International Journal of Language & Communication Disorders

INT J LANG COMMUN DISORD, XXXX 2019,
VOL. 00, NO. 0, 1–12

Research Report

The role of linguistic and cognitive factors in emotion recognition difficulties in children with ASD, ADHD or DLD

Joanna Löytömäki†‡, Pasi Ohtonen§, Marja-Leena Laakso¶ and Kerttu Huttunen‡||#**

†Department of Logopedics, Abo Akademi University, Turku, Finland
‡Faculty of Humanities/Research Unit of Logopedics and Child Language Research Center, University of Oulu, Oulu, Finland
§Division of Operative Care, Medical Research Center Oulu, Oulu University Hospital and University of Oulu, Oulu, Finland
¶Department of Education, University of Jyväskylä, Jyväskylä, Finland
||PEDEGO Research Unit, University of Oulu, Oulu, Finland
#Medical Research Center Oulu, Oulu, Finland
**Oulu University Hospital, Department of Otorhinolaryngology, Head and Neck Surgery, Oulu, Oulu, Finland

(*Received July 2018; accepted October 2019*)

Abstract

Background: Many children with neurodevelopmental disorders such as autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD) or developmental language disorder (DLD) have difficulty recognizing and understanding emotions. However, the reasons for these difficulties are currently not well understood.
Aims: To compare the emotion recognition skills of children with neurodevelopmental disorders as well as those children's skills with the skills of their typically developing (TD) age peers. Also, to identify the role of underlying factors in predicting emotion recognition skills.
Methods & Procedures: The 6–10-year-old children ($n = 50$) who participated in the study had either ASD, ADHD or DLD and difficulties recognizing emotions from face and/or in voice. TD age peers ($n = 106$) served as controls. Children's skills were tested using six forced-choice tasks with emotional nonsense words, meaningful emotional sentences, the FEFA 2 test, photographs, video clips and a task in which facial expressions and tones of voice had to be matched. Expressive vocabulary, rapid serial naming, auditory and visual working memory and Theory of Mind skills were explored as possible explanatory factors of the emotion recognition difficulties of the diagnosed children.
Outcomes & Results: Children with ASD, ADHD or DLD did not significantly differ from each other in their linguistic or cognitive skills. Moreover, there were only minor differences between children with these diagnoses in recognizing facial expressions and emotional tone of voice and matching the two. The only significant difference was that children with ADHD recognized facial expressions in photographs better than children with DLD. The participants with diagnoses scored significantly lower than the controls in all but one emotion recognition tasks presented. According to the linear regression analysis, first-order Theory of Mind skills predicted the delay relative to typical development in the recognition of facial expressions in the FEFA 2 test, and expressive vocabulary and working memory skills together predicted the delay in the recognition of emotions in the matching task.
Conclusions & Implications: Children with ASD, ADHD or DLD showed very similar emotion recognition skills and were also found to be significantly delayed in their development of these skills. Some predictive factors related to linguistic and cognitive skills were found for these difficulties. Information about impaired emotion recognition and underlying linguistic and cognitive skills helps to select intervention procedures. Without this information, therapy might unnecessarily focus on only symptoms.

Keywords: emotion, neurobiological, specific language impairment, developmental language disorder, facial expressions, tone of voice, prosody, development, delay.

Address correspondence to: Joanna Löytömäki, Faculty of Humanities/Research Unit of Logopedics and Child Language Research Center, University of Oulu, P.O. Box 1000, FI-90014 University of Oulu; e-mail: joanna.loytomaki@puheterapeutti.fi

(*Received July 2018; accepted October 2019*)

International Journal of Language & Communication Disorders
ISSN 1368-2822 print/ISSN 1460-6984 online © 2019 Royal College of Speech and Language Therapists
DOI: 10.1111/1460-6984.12514

What this paper adds

What is already known on the subject

Research suggests that children with neurodevelopmental disorders such as ASD, ADHD and DLD display emotion recognition problems as one of their social–emotional difficulties, but the underlying factors of and interrelationships between these difficulties are largely unknown.

What this paper adds to existing knowledge

This study uncovered some underpinnings of emotion recognition skills in the three diagnostic groups studied. The possibility of ASD, ADHD and DLD sharing more symptoms than have previously been identified is starting to be widely accepted among both researchers and clinicians. To our knowledge, no prior studies have included all three groups in the same study to explore children's abilities to recognize emotions from facial expressions and tones of voice and match the information from these two modalities.

What are the potential or actual clinical implications of this work?

Focusing intervention only on emotion recognition skills may not suffice. It is important for clinicians also to focus therapy on improving (emotional) vocabulary, Theory of Mind abilities, and auditory and visual working memory skills because deficits in these may hamper emotion recognition.

Introduction

Emotion recognition skills are important parts of communication and children's social–emotional development. In contrast to typically developing (TD) children, children with neurodevelopmental disorders often face difficulties in the development of emotion recognition skills which are linked to the development of social competence, peer relations and self-esteem (Evers *et al.* 2015). Emotion recognition abilities are complex set of skills, which are also affected by an individual's linguistic and cognitive abilities (Keltner *et al.* 2014: 187–194).

The present study explores the emotion recognition abilities of children with autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD) and developmental language disorder (DLD). These disorders have similar etiological background consisting of genetic or hereditary factors (Onnisa *et al.* 2018, Simpson *et al.* 2015, Smoller *et al.* 2013), and they quite often occur together, which may suggest at least partly shared neurobiological and etiological background (Rommelse *et al.* 2010, see also Bishop 2010). The growing understanding of the similarities and differences in these three diagnostic groups has also affected the diagnostic criteria of ASD, ADHD and DLD (or specific language impairment—SLI) as they have been undergoing change in both the ICD-11 and the recently published DSM-5 American Psychiatric Association (APA) (2013) classifications. Additionally, increased attention has recently been paid to the occurrence of a broad spectrum of other difficulties, such as attention problems, social impairment, and behavioural and emotional disorders which sometimes accompany DLD (Loucas *et al.* 2008, Taylor *et al.* 2015). As groups, children with ASD, ADHD and DLD have all been found to experience overlapping difficulties not only in neurodevelopmental domains (e.g., Geurts and Embrechts 2008) but also in emotion recognition skills. For example, Waddington *et al.* (2018) found that children with ADHD had problems in recognition of facial expressions and tones of voice to the same extent as children with ASD. Studies where overlaps in emotion recognition difficulties between DLD and ASD or ADHD have been demonstrated are still sparse, although descriptions of difficulties within these diagnostic groups exist. For example, a fairly recent study by Taylor *et al.* (2015) showed that children with ASD ($n = 29$) and DLD ($n = 18$) both performed poorly in recognizing emotions from face or voice. They also stressed the importance of language ability in affective understanding. These cross-domain relationships are important to be explored further to create a more comprehensive picture of these neurodevelopmental disorders.

Emotion recognition difficulties in children with ASD, ADHD and DLD

Recognizing emotions from face, voice or social context is difficult for many children with ASD, and evidence of poor facial emotion recognition is found in several studies (e.g., Golan *et al.* 2008, Leung *et al.* 2013). Fewer studies have focused on children with ASD recognizing emotions from voice, but some researchers have found impairment in their ability to process emotional prosody (e.g., Demopoulos *et al.* 2013) and interpreting them in social contexts.

Like children with ASD, children with ADHD have demonstrated difficulties with emotion recognition (Demopoulos *et al.* 2013), although contrary findings also exist (see the review by Borhani and Nejati 2018). In ADHD, inattention, impulsivity and hyperactivity hamper a child's development. Differing views have been presented favouring either impaired executive functions (Sinzig *et al.* 2008) or linguistic problems (Geurts and Embrechts 2008) as underpinning emotion recognition difficulties of children with ADHD. Of the studies reviewed by Borhani and Nejati (2018), 18 out of 26 had found facial emotion recognition problems in children and adults with ADHD.

Moreover, children with DLD have also been demonstrated to have emotion recognition difficulties (Boucher *et al.* 2000, Taylor *et al.* 2015). Compared with children with ASD, their skills have been far less researched, but some findings have been presented on the nature of their social–emotional skills (Botting and Conti-Ramsden 2008). There is evidence that children and adolescents with DLD have difficulty recognizing both simple (such as joy or anger) and complex (such as embarrassment) emotions (Boucher *et al.* 2000, Taylor *et al.* 2015). Children with DLD often have difficulties with social competence, and this has usually been thought to result from poor communication skills (Spackman *et al.* 2005). Spackman *et al.* (2005), however, also argued that difficulties the children with DLD have with social competence are partly due to emotion recognition difficulties.

In the recent study of Taylor *et al.* (2015), TD children ($n = 61$) were compared with children with ASD ($n = 29$) and children with DLD ($n = 18$). They found that the 4–11-year-old children with ASD and DLD performed significantly worse than TD children at recognizing emotions from both face and voice. The authors concluded that emotion recognition difficulties were specifically due to poor linguistic skills in both groups. Boucher *et al.* (2000) found that 9-year-old children with DLD ($n = 19$) recognized emotions from faces and named emotions even worse than same-age children with ASD ($n = 19$).

Linguistic and cognitive abilities and emotion recognition

Based on what is already known about emotion recognition skills, the strongest evidence that currently exists concerns their associations with Theory of Mind (ToM), language and working memory skills. ToM skills have been found to be delayed in children with ASD and some children with ADHD and DLD (Loukusa *et al.* 2014). Furthermore, ToM skills are strongly and directly associated with emotion recognition problems, without mediating factors (Baron-Cohen *et al.* 1985). Language has been shown to be an important mediating factor in emotion recognition skills (Loucas *et al.* 2008). Alloway *et al.* (2009) noticed that there is also evidence of shared deficits among children with ASD, ADHD and DLD in, for example, attention skills, short-term memory and self-regulation skills. They found that working memory difficulties were extremely prevalent in all these diagnostic groups, with the children with DLD having the most severe problems.

In sum, it is still unclear which underlying factors can explain the emotion recognition difficulties in these three disorders and to what extent different language and cognitive functions are needed for emotion recognition even in typical development. To the best of our knowledge, no other study has included both ASD, ADHD and DLD and explored the interrelationships between the linguistic and cognitive factors and emotion recognition as extensively as we aim to do in this study.

Aims of the study

We aimed to determine the level of emotion recognition skills, their differences from those of TD children and the possible underlying linguistic and cognitive factors of these difficulties in children with ASD, ADHD and DLD.

Methods

Participants

Children who had ASD, ADHD or DLD ($n = 50$) and were 6–10 years old took part this study (table 1). They were recruited from both northern and southern Finland through hospitals, privately practising speech and language and occupational therapists, psychologists, schools and parent organizations. From here on, these three diagnostic groups are together called the clinical group. Additionally, a group of TD children 6–10 years old ($n = 106$), 20–22 children in each age group, were recruited to serve as controls. They were recruited from daycare centres and schools and were judged to be TD based on the report of their parents (questionnaire filled out). The study protocol was approved by the Ethical Committee of the Northern Ostrobothnia Hospital District, and written informed consent was obtained from the parents. Written consent was also obtained from those children who were able to read the research note and sign the consent form.

The inclusion criteria for the clinical group were: (1) diagnosis of ASD, ADHD or DLD; (2) difficulties recognizing emotions from face and/or in voice as reported by parents or a professional (speech and language therapist, occupational therapist, psychologist, kindergarten teacher or teacher); (3) age between 6 and 10 years; (4) non-verbal IQ > 85; (5) monolingual Finnish-speaking family; and (6) child's vision, hearing, motor and attention skills sufficient for test situations. Some participants had the diagnostic label of SLI as they were diagnosed according to the ICD-10 (National Institute for Health and Welfare 2011, World Health Organization (WHO)

Table 1. Demographic characteristics of the children with neurodevelopmental disorders and the typically developing (TD) children

	ASD ($n = 20$)	ADHD ($n = 17$)	DLD ($n = 13$)	Total ($n = 50$)	TD ($n = 106$)
Male:female	18:2	14:3	9:4	41:9	47:59
CHR age (years), mean (SD)	8.25 (1.21)	8.06 (1.30)	7.62 (1.61)	8.02 (1.25)	8.02 (1.42)
Single diagnosis	11	9	10	30	n.a.
Comorbid diagnoses	9	8	3	20	n.a.

Note: CHR age = chronological age; ASD, autism spectrum disorder; ADHD, attention deficit hyperactivity disorder (including three with ADD); DLD, developmental language disorder; n.a., not applicable.

1992), which is still in clinical use. However, the up-to-date label of DLD will be used here, as this term does not exclude cognitive, motor or emotional difficulties and will also be included in the upcoming ICD-11 classification (Bishop *et al.* 2017). Per the exclusion criteria, the children in the clinical group were not allowed to have any psychiatric diagnoses, such as depression. Information needed to fulfil the inclusion criteria and detailed information about their child's diagnosis and other issues was gathered from the parents using a questionnaire.

Demographic characteristics of the children can be found in table 1. The mean age of the children with one of the diagnoses was 8.02 years, which matched the mean age of the TD children. Neither the age of the children nor the male-to-female ratio differed significantly between the three diagnostic groups. In the whole clinical group ($n = 50$), the proportion of males was significantly higher than in the TD 106 age peers (Fisher's Exact test, $p < 0.001$).

Of the children with neurodevelopmental disorders, 30 had a single diagnosis, but 20 children had at least one comorbid diagnosis in addition to that which we judged to be the primary one (see below). Of these 20 children, six had been diagnosed with both ASD and ADHD, seven had ADHD and DLD, three had ASD and DLD, and four had all three diagnoses. Therefore, as many as 48% of the participants had comorbid diagnoses despite the diagnostic criteria of SLI (nowadays increasingly called DLD) in ICD-10 (National Institute of Health and Welfare 2011, WHO 1992). According to the ICD-10, a child's language difficulties cannot be explained by other disorders (see also Rapin and Allen 1988).

Most ($n = 17$) of the 20 children with ASD had Asperger's syndrome (AS) (code F84.5 in ICD-10) as their diagnosis, and three had diagnosis of pervasive developmental disorders, unspecified (F84.9). Three of the children grouped under ADHD had attention deficit disorder (ADD), but since ADD is categorized under the diagnostic code of ADHD (F90.0), we will use ADHD to cover these cases.

In the case of comorbid diagnoses, the primary diagnosis was determined based on a child's symptom profile in the medical records provided by parents. If there was no additional information available, the decision was based on scientific and clinical literature. For example, if diagnoses of both ASD and ADHD had been given to the same child, complying with the clinical routine used in Finland (Moilanen 2011), ASD was determined to be the primary one. If a child had medication for ADHD and he or she also had DLD, ADHD was judged to be more severe and therefore the primary diagnosis. Additionally, seven of the participants also had subsidiary diagnoses such as a motor function disorder or Tourette´s syndrome. Of the children with ADHD, 12 out of 17 had medication for their ADHD symptoms. There were 35 children (70%) in the clinical group who had received or had ongoing speech therapy during the time of data collection, and 15 children (30%), who did not.

Measurements

Data were collected by formal testing using vocabulary, rapid serial naming, working memory, ToM and emotion recognition tasks. All children with a diagnosis were tested individually, and the assessments were both audio- and video-recorded for purposes of scoring. To avoid testing fatigue, the test sessions were usually scheduled to take place on two consecutive days. The same was applied to the TD 7–8-year-olds who served as controls, but for the sake of time efficiency, all the TD 9–10-year-olds were tested in groups. This procedure was judged to give valid and unbiased results as we checked that the emotion recognition results of the 7–8-year-old TD children ($n = 42$) tested individually in our study did not significantly differ from those of 7–8-year-old TD children ($n = 43$) tested in groups (these data have been collected earlier and are reported elsewhere). During group testing, stimuli were presented using a computer, loudspeakers and a data projector, and children marked down their responses on paper.

Linguistic and cognitive tasks

The linguistic skills of the participants with neurodevelopmental disorders were explored in the domain of expressive vocabulary by using the validated Finnish version (Laine *et al.* 1997) of the Boston Naming Test (Kaplan *et al.* 1983). Rapid automatized naming was tested by using two subtests of the validated Rapid Serial Naming Test (Ahonen *et al.* 1999), that is, for the most part, based on the Rapid Automatized Naming Test (RAN; Denckla and Rudel 1974). Delay relative to typical development was calculated by using the results of the validation samples documented in the test manuals. Two-category delay variables were formed for the scores of the Boston Naming Test and the two RAN subtests to separate children performing at their age level from those who performed > 1 SD below it. This categorization of the data was performed because no closer information for relating the test results obtained to typical development were given; only mean and SDs for different age groups were available in the test manual of the Finnish version of the Boston Naming Test and RAN. The same –1 SD criterion has also been used by Taylor *et al.* (2015) and we obtained comparability by using the same criterion in our study.

Memory skills were assessed using both the auditory and visual short-term sequential memory tasks in the two subtests of the validated Finnish version (Kuusinen and Blåfield 1974) of the Illinois Test of Psycholinguistic Abilities (ITPA) (Kirk *et al.* 1968). Delay in months relative to age peers was determined based on the mean scaled scores representing typical development at each age level documented in the test manual (Kuusinen and Blåfield 1974).

ToM skills were assessed with first- and second-order false belief tasks. The Sally-Anne Test (Baron-Cohen *et al.* 1985) was used as the first-order false belief task. To help to diminish the memory load, a girl and a boy doll were used, as suggested by Doherty (2009: 10), as opposed to the original set-up in which two girl dolls are used. The Ice Cream Van story based on Perner and Wimmer (1985) was used as the second-order ToM false belief task, with some modifications made to shorten and simplify it. A justification question was also presented requiring the child to provide reasons for his or her answer to the second-order ToM question. All ToM tasks were scored as pass or fail.

Emotion recognition tasks

Emotion recognition skills were assessed by using forced-choice tasks of facial expression and tone of voice recognition, and matching them.

In the emotional nonsense word task, children listened to 18 items comprising nonsense words 'paappa', 'piippi' and 'paippi', either as single words (in nine items) or (also in nine items) embedded in a linguistically neutral carrier phrase ('Now I say . . . '), with the prosody of the carrier phrase matching the target tone of voice. Nonsense words representing joy, anger and sadness all randomly occurred six times among the 18 items. In the next task, children listened to three- to four-word sentences in which the linguistic content complied with the emotion with which the sentences were spoken (e.g., 'Don't come here!' with an angry voice). With its 11 items, this task contained joy, anger and sadness, all occurring twice as targets, and fear, surprise, disgust, shame and neutral tones of voice occurring once as targets.

The 'Faces' submodule of the Finnish version of the FEFA 2 test (The Frankfurt Test and Training of Facial Affect Recognition; Bölte *et al.* 2013, Bölte and Poustka 2003) was used as a standardized task to assess children's facial emotion recognition skills. This computerized test consists of 50 photographs depicting seven different emotions and their labels as response choices (joy, anger, sadness, fear, surprise, disgust and neutral). The test administrator read aloud the alternative choices for illiterate children. The original version of the Faces submodule has been reported to have excellent psychometric properties: internal consistency is 0.95 as measured by Cronbach's alpha and stability $r = 0.92$ based on test–retest measurements (Bölte *et al.* 2002). Additionally, a set of eight photographs depicting eight different emotions (the six basic emotions, and ashamed and neutral expressions), posed by two children and two adult professional actors, was constructed and shown with four verbal labels spoken by the test administrator as response choices. To test facial emotion recognition skills using dynamic input, a set of eight video clips of 4 s each (again, comprising the six basic emotions, and ashamed and neutral expressions) was created and shown with four verbal labels as response choices. In all clips but the one illustrating a neutral facial expression, the expression developed from neutral into the target emotion.

A task in which facial expressions and tone of voice had to be matched comprised 11 different items (the six basic emotions, and ashamed and neutral expressions). Children needed to point at a facial expression with which they thought the sentence they heard matched. All the emotions were posed, and the sentences were spoken by two speech and language therapists. All the emotion recognition tasks were also conducted on the controls, 106 TD children.

Statistical analyses

SPSS for Windows (vv. 24 and 25) was used for the statistical analyses. Because tasks of different lengths and maximum scores were used in emotion recognition testing, their results were expressed as per cent performance to allow comparability. Additionally, for the emotion recognition tasks, a delay in relation to TD age peers was also calculated and used in scoring. This was done to obtain further comparability between the different tests and tasks and children of varying ages and uncover the emotion recognition profile of the children in different diagnostic groups. Delay variables were also needed in the linear regression analysis. In all emotion recognition tasks, the TD sample was used in forming the delay variables of the clinical group.

Reliability of the measurements was explored with Pearson's correlation coefficient and Cronbach's alpha. Differences in the ages between different child groups and whether emotion recognition ability differed between children with single diagnosis and children with at least one comorbid diagnosis were investigated with independent sample *T*-test. One-way analysis of variance (ANOVA), independent sample and paired sample *T*-tests, chi square and Fisher's exact test were used to compare linguistic and cognitive test results and the emotion recognition results between the different diagnostic groups and between children with diagnoses and typical development.

Linear regression analysis was used to explore which combinations of linguistic and cognitive factors would predict the level of children's emotion recognition skills. Three tasks—emotional nonsense words, FEFA 2 test of facial expressions and matching facial expressions and tone of voice—were chosen as dependents. All measured linguistic and cognitive factors served as independent variables to find the best possible model for predicting emotion recognition skills. Because of the sample size ($n = 50$), only models with a maximum of two independent variables were used. The diagnosis of DLD was used as a reference group because they performed most poorly. Preliminary analysis was performed to ensure that the assumptions of normality were met. A factor was left in the regression model if it had $p < 0.05$ or a significant impact on the model's R^2 value (> 10% change). Given the fairly large number of statistical tests performed, *p*-values should be interpreted with caution.

Results

The linguistic, cognitive and emotion recognition skills in children with ASD, ADHD and DLD ($n = 50$) were explored. Depending on the task or test, between 39 and 50 children accomplished each task. Missing data were caused by children's cooperation skills and children not yet knowing numbers and letters to be named in one RAN subtest. However, we perceive the results to be valid without any data imputation because the few (at maximum, four per diagnostic group) missing results were evenly or randomly spread across the three diagnostic groups.

Linguistic and cognitive skills

The mean raw scores and the number of children performing more poorly than 1 SD below age level in the linguistic and cognitive tasks can be found in table 2.

We wanted to know if the linguistic and cognitive skills in the three diagnostic groups would differ from the group of TD children. Because the vocabulary and rapid serial naming skills of the TD children serving as controls in this study were not tested, no statistical testing could be performed using their results. Instead, we used age norms from the test manuals or references from Loukusa (2007). Overall, ANOVA showed that there was no difference between the diagnostic groups in the raw scores compared with age norms in RAN time subtest 'Objects' ($F(2,38) = 0.776$, $p = 0.467$), in RAN time 'Colours, numbers and letters' ($F(2,36) = 1.504$, $p = 0.236$), or in ITPA auditory ($F(2,44) = 1.750$, $p = 0.186$) or visual ($F(2,44) = 0.627$, $p = 0.539$) short-term memory. Additionally, raw scores of the Boston Naming Test ($F(2,47) = 3.207$, $p = 0.049$) were not, after Bonferroni correction, significantly different between the three groups of children with neurodevelopmental disorders.

Compared with age norms or age references, children with DLD were significantly delayed in their expressive vocabulary and in their ability to rapidly name objects (table 3). All the three diagnostic groups were significantly delayed in their auditory short-term memory skills and children with DLD also in their visual short-term memory skills.

For the ToM tasks, the clinical group was found to both pass the ToM 1 task significantly less often than the 106 TD controls (χ^2 (3) = 12.631; $p = 0.006$), and to less often give the right answer to the ToM 2 question (χ^2 (3) = 8.277; $p = 0.041$). Specifically, children in both the group of children with ADHD (Fisher's exact test, $p = 0.027$) and DLD (Fisher's exact test, $p = 0.007$) passed the ToM 1 task less often than their TD age peers and children with ADHD could also less often give the correct ToM 2 explanation (Fisher's exact test, $p = 0.028$).

Emotion recognition skills

Recognition of tone of voice in nonsense words and in meaningful sentences were found to correlate significantly (Pearson's correlation coefficient = 0.334, $p = 0.018$) in the clinical group. However, Cronbach's alpha was low (0.498). A low alpha level was probably due to low variability in the task of meaningful sentences; 17 out of 50 children scored at maximum, the mean accuracy of the clinical group was 85% (SD = 16.837) and median 91% (interquartile range = 20). Instead, recognition of facial expressions correlated significantly between the FEFA 2 test, the task containing photographs (Pearson's correlation coefficient = 0.634, $p < 0.001$) and the task containing video clips ($r = 0.590$, $p < 0.001$), and Cronbach's alpha indicated good reliability (0.834).

Table 2. Results of the linguistic and cognitive tasks of children with neurodevelopmental disorders with age norms or references

	ASD ($n = 20$)	ADHD ($n = 17$)	DLD ($n = 13$)	Total ($n = 50$)	Age norms or references for TD 8-year-olds
Boston Naming Test raw score					
Mean (SD)	42 (9)	41 (6)	36 (7)	40 (8)	43 (7)[a]
At age level: > 1 SD below age level, *N*	16:4	13:4	7:6	36:14	
RAN time, subtest 'Objects'					
Mean (s) (SD)	61 (17)	70 (31)	70 (16)	67 (23)	56 (12)
At age level: > 1 SD below age level, *N*	9:8	8:6	5:5	22:19	
RAN time, subtest 'Colours, Numbers and Letters'					
Mean (s) (SD)	53 (21)	62 (33)	72 (27)	60 (27)	51 (15)
At age level: > 1 SD below age level, *N*	12:5	9:4	6:3	27:12	
ITPA auditory working memory					
Mean scaled scores (SD)	31 (5)	32 (7)	29 (5)	31 (6)	36
At age level: below age level, *N*	4:16	3:13	0:13	7:42	
Below age level (months), mean (SD)	29 (19)	30 (19)	38 (16)	33 (18)	
Below age level (months), minimum–maximum	8–58	15–62	5–63	5–63	
ITPA visual working memory					
Mean scaled scores (SD)	34 (13)	30 (9)	31 (9)	32 (11)	36
At age level: below age level, *N*	5:13	4:11	2:10	11:34	
Below age level (months), mean (SD)	22 (19)	25 (25)	32 (25)	26 (23)	
Below age level (months), minimum–maximum	6–56	1–80	1–76	1–80	
ToM 1 task, pass:fail[b]	15:5	11:6	7:6	33:17	93:13
ToM 2 task, pass:fail[b]	12:8	10:7	8:5	30:20	76:30
ToM 2 task: justification, pass:fail[b]	8:12	2:15	2:11	12:38	44:62

Notes: Boston Naming Test = expressive vocabulary naming test (Laine *et al.* 1997; Kaplan *et al.* 1983); RAN = Rapid Automatized Naming Test (Ahonen *et al.* 1999; Denckla and Rudel 1974); ITPA = The Illinois Test of Psycholinguistic Abilities (Kuusinen and Blåfield 1974; Kirk *et al.* 1968); ToM 1 task = Theory of Mind first-order false belief task (Baron-Cohen *et al.* 1985); ToM 2 = Theory of Mind second-order false belief task (Perner and Wimmer 1985); ToM 2 task: justification = can a child provide a justification for the answer in the ToM 2 task.
[a]Age references from Loukusa (2007).
[b]Results of typically developing (TD) children are based on the 106 children (mean age = 8.02 years, minimum = 6, maximum = 10 years) tested in the present study.

Table 3. Comparison of the results of linguistic and cognitive tasks of the children with neurodevelopmental disorders with age norms or references with *p*-values from the Paired Sample *T* test or Fisher's Exact test

	ASD ($n = 20$)	ADHD ($n = 17$)	DLD ($n = 13$)
Boston Naming Test raw score[a]	$t(19) = -1.053, p = 0.306$	$t(16) = -1.170, p = 0.259$	$t(12) = -3.381, p = 0.005$
RAN time, subtest 'Objects'	$t(16) = 1.855, p = 0.082$	$t(12) = 1.767, p = 0.103$	$t(9) = 2.288, p = 0.048$
RAN time, subtest 'Colours, Numbers and Letters'	$t(16) = 1.056, p = 0.307$	$t(12) = 1.463, p = 0.169$	$t(8) = 2.257, p = 0.054$
ITPA auditory working memory	$t(18) = -4.230, p = 0.001$	$t(14) = -3.690, p = 0.002$	$t(12) = -8686, p < 0.001$
ITPA visual working memory	$t(18) = -1.389, p = 0.182$	$t(14) = -1.568, p = 0.139$	$t(11) = -2.578, p = 0.026$
ToM 1 task[b]	$\chi^2 = 2.170, p = 0.165$	$\chi^2 = 5.842, p = 0.027$	$\chi^2 = 0.9767, p = 0.007$
ToM 2 task[b]	$\chi^2 = 1.037, p = 0.304$	$\chi^2 = 1.100, p = 0.393$	$\chi^2 = 0.542, p = 0.524$
ToM 2 task justification[b]	$\chi^2 = 0.006, p = 1.000$	$\chi^2 = 5.354, p = 0.028$	$\chi^2 = 3.205, p = 0.127$

Note: [a]Compared with age references of Loukusa (2007).
[b]Compared with the 106 typically developing (TD) children tested in the present study.

The ANOVA showed that the performance of the children with a diagnosis was significantly below that of the controls in all emotion recognition tasks except in the ability to match emotion input from face and voice (table 4), with the recognition ability profile across different tasks being similar in all diagnostic groups. When looking at the mean per cent performance (raw scores), one difference was found between the diagnostic groups ($F(2,46) = 4.407$, $p = 0.024$); children with ADHD (mean = 77.4%, SD = 15) performed significantly better than children with DLD (mean = 60.9%, SD = 13) in the recognition of facial expressions from photographs task ($p = 0.020$).

The largest mean difference between the clinical group compared with typically developing children was found in recognition of emotions from photographs (11% units, $F(3,150) = 8.470$, $p < 0.001$), and the smallest difference was found in recognition of emotions from meaningful sentences (5% units, $F(3,149) = 4.044$, $p = 0.008$).

Because delay variables were needed to be formed for the linear regression analysis (see below), all the

Table 4. Mean per cent performance in emotion recognition tasks of the different diagnostic groups compared with typically developing (TD) children ($n = 106$) with p-values from one-way analysis of variance (ANOVA) with Bonferroni correction

	ASD ($n = 20$)	ADHD ($n = 17$)	DLD ($n = 13$)	TD ($n = 106$)
Recognizing emotions from voice				
Nonsense words	57.6 (13.2), $p = 0.868$	51.6 (17.2), $p = 0.017$	48.7 (13.8), $p = 0.006$	63.2 (14.55)
Meaningful sentences	88.6 (14.2), $p = 1.000$	86.7 (11.6), $p = 1.000$	78.2 (24.2), $p = 0.005$	90.5 (9.54)
Recognizing emotions from face				
FEFA 2 test	64.9 (13.1), $p = 0.002$	67.9 (7.9), $p = 0.120$	57.5 (17.4), $p < 0.001$	74.7 (10.00)
Photographs	70.0 (18.4), $p = 0.031$	77.4 (14.2), $p = 1.000$	60.9 (12.5), $p < 0.001$	81.0 (15.42)
Video clips	78.6 (15.6), $p = 0.475$	78.1 (15.0), $p = 0.422$	67.6 (17.4), $p < 0.001$	85.0 (13.65)
Matching emotion input from face and voice				
	77.5 (18.3), $p = 0.101$	76.5 (22.5), $p = 0.080$	78.4 (22.5), $p = 0.448$	86.3 (11.28)

Note: Nonsense words = recognition of an emotion from single nonsense words or nonsense words embedded in a carrier sentence; meaningful sentences = recognition of an emotion from a meaningful sentence; FEFA 2 test = The Frankfurt Test and Training of Facial Affect Recognition 2 (Bölte *et al.* 2013); photographs = eight photographs depicting eight different emotions; video clips = eight video clips depicting the same emotions as the photographs; matching task = matching facial expressions with the respective tone of voice.

emotion recognition variables presented from hereon are delay variables (clinical group was compared with the group of TD controls), except in the raw score results shown in table 4. Although there were proportionally clearly more females in the TD control group (56%) than in the clinical group (18%), comparisons in emotion recognition were seen to be relevant because there was no significant difference in the results in any of the emotion recognition tasks between the TD females and males ($p = 0.659$–0.877).

A subgroup analysis using independent sample T-test did not reveal any significant differences ($t(48) = –1.249$, $p = 0.223$ to $t(47) = 0.112$, $p = 0.911$) in the emotion recognition skills between the children with a single diagnosis ($n = 30$) and those with comorbid diagnoses ($n = 20$). Then we looked at the possible differences in emotion recognition abilities as the function of the diagnosis of ASD, ADHD and DLD. When the diagnostic groups were compared with the group of TD controls (using delay variables), ANOVA with Bonferroni correction as the post hoc analysis did not indicate any differences between the three diagnostic groups in the six emotion recognition tasks ($F(2,47) = 2.519$, $p = 0.91$ to $F(2,47) = 0.048$, $p = 0.953$).

Interrelationships between linguistic, cognitive and emotion recognition skills

Linear regression analysis was applied to determine which linguistic and cognitive factors of their combinations would best predict the selected emotion recognition abilities. Since there were neither differences between the children with single or comorbid diagnoses nor wide-scale differences between the diagnoses of ASD, ADHD or DLD in emotion recognition skills, the whole clinical group ($n = 50$) was used as one in the linear regression analysis.

The nonsense word task, the FEFA 2 test, and the matching task were chosen as the emotion recognition variables in the regression analyses, because they had the largest number of items and they represent both facial and vocal emotion recognition skills. The variables were entered as delay variables (in comparison with the TD children) in the regression models. As the children with DLD performed slightly more poorly (although non-significantly) than children with ASD or ADHD in the above mentioned three tasks, the DLD group was used as the constant (reference group) in the regression analyses.

No model had significant predictive value for the nonsense word task. The best predictive models for the FEFA 2 test and the matching task are found in table 5. Passing the ToM 1 task was a significant predictor of the FEFA 2 test results contributing to, on average, a smaller delay by 8% units compared with those not passing the task. In this same model, children with ADHD performed significantly better in the FEFA 2 test than the children with DLD. Children with ADHD and ASD had, on average, 9% and 5% units smaller delays in FEFA 2 scores compared with children with DLD, respectively. The delay was 3% units larger in males than in females, and it decreased by 2% units for every increasing age year, but neither sex nor age were significant predictors of FEFA 2. This model predicted 17.9% ($R^2 = 0.179$) of the variation in the recognition of facial expressions in the FEFA 2 test.

The model in table 5 predicted 15.9% of the variation in the matching task ($R^2 = 0.159$), with the Boston Naming Test being a marginally significant predictor ($p = 0.05$). Those children who scored > 1 SD below their age level in the expressive vocabulary test had a mean of 10% units larger delay in the matching task than children with age-appropriate expressive vocabulary. The ITPA auditory and visual working memory subtests themselves were not significant predictors, but

Table 5. Best models found through linear regression analysis for the FEFA 2 test and the matching task as dependent variables

	$R^2 = 0.179$			
Delay in FEFA 2	*B*	*p*	CI Lower bound	CI Upper bound
Constant (DLD)	22.43	0.001	14.89	29.98
ASD	−4.61	0.28	−13.09	3.87
ADHD	−9.13	0.039	−17.80	−0.472
ToM 1	−7.60	0.037	−14.70	−0.50
	$R^2 = 0.159$			
Delay in matching task	*B*	*p*	CI Lower bound	CI Upper bound
Constant (DLD)	−0.080	0.98	−10.58	10.42
Boston > 1 SD below age level	9.97	0.050	−0.17	19.95
ITPA	0.24	0.071	−0.02	0.51

Notes: Variables were entered as delay variables (in comparison with the typically developing children).
CI = 95% confidence interval for B; ITPA = auditory or visual memory, which ever was worse – expressed as delay in months compared with the age norms in the test manual.

when entered into the model, the delay in the Boston Naming Test scores and either of the ITPA subtests together predicted the scores of the matching task. Age was not a significant predictor in the matching task.

Discussion

The main findings of this study indicate that children with ASD, ADHD or DLD had shared difficulties in all emotion recognition tasks. They were significantly delayed in emotion recognition skills compared with TD age peers in all tasks measured. No significant difference was found between the three diagnostic groups other than that of the children with ADHD, who had better per cent scores than children with DLD in the recognition of facial expressions from photographs task. Furthermore, there was no significant difference in children's emotion recognition skills depending on whether the child had a single diagnosis or comorbid diagnoses.

Our regression analysis showed that the diagnosis and the first-order ToM false belief skill predicted children's delays in facial emotion recognition in the FEFA 2 'Faces' subtest, with children with ADHD having the smallest delay. Additionally, the delay in expressive vocabulary measured with the Boston Naming Test and delay in either ITPA auditory or visual working memory subtest scores together predicted the degree of delay in the task in which facial expressions and tone of voice were matched with each other. Similar findings have been found when the emotion recognition skills of children with ASD and DLD have been compared with each other (e.g., Boucher *et al.* 2000, Golan *et al.* 2008, Taylor *et al.* 2015), but before our study, no research has compared these difficulties in ASD, ADHD and DLD together.

There were far fewer predictive factors between linguistic and cognitive factors and emotion recognition abilities than we expected to find. There could be several reasons for this. First, of the factors we could test statistically, there were no striking differences between the children with neurodevelopmental disorders and the TD children in the linguistic and cognitive tasks except in the ToM 1 task and in answering the ToM 2 justification question. On that basis, linguistic and cognitive skills cannot be expected to be strong explanatory factors of difficulties in emotion recognition skills in the present data. Second, differences in emotion recognition skills between children with diagnoses and TD children were not large; their means differed only from 5% to 11% units. It is possible that additional explanatory factors could be found in children with more severe symptom profiles. The diagnostic groups were also relatively small in size ($n = 13$–20). Thus, the regression analysis only allowed two independent variables to be entered into each model at one time. The best predictive models explained up to 17.9% of the variation in emotion recognition skills, which is a moderate figure and typical of studies on human behaviour.

Language has been found to be an important factor in emotion recognition skills (Boucher *et al.* 2000, Spackman *et al.* 2005, Taylor *et al.* 2015). In the present study, 70% of the children in the clinical group had received prior or had ongoing speech therapy, and this was not limited only to the children with DLD. However, only 28% of the children had a delay of –1 SD or more in the vocabulary task which may suggest that other aspects of language than only expressive vocabulary are needed in emotion recognition. For example, some children with ASD, ADHD and DLD have been shown to have difficulties in the use of language, that is, pragmatics (e.g., Green *et al.* 2014, Helland and Helland 2017). Ideally in this study, too, the language assessments should also have covered more than just expressive vocabulary and rapid serial naming.

Research suggests that ToM skills are strongly associated with social–emotional skills (Golan *et al.* 2008). According to a recent meta-analysis by Bora and Pantelis (2016), both facial and vocal emotion recognition and ToM skills are significantly impaired in individuals with ADHD with large effect sizes of 0.40–0.44. In the present study, the ADHD group did not differ significantly from the ASD and DLD groups in ToM skills. However, in the regression analysis model in which children with ADHD had smaller delays in expressive vocabulary, passing the ToM 1 task predicted emotion recognition from facial expressions. In contrast, the ASD group did not differ from the other groups in ToM and emotion recognition skills, though, based on earlier research findings (e.g., Loukusa *et al.* 2014), we expected to see a difference. This may be due to the small sample size, and because our sample of children may have been somewhat biased; according to our inclusion criterion, the children's nonverbal IQ had to be > 85, and therefore our participants did not represent the whole range of children, especially with ASD.

Study limitations

The biggest limitations restricting the generalizability of our results are the fairly small number of participants and the unequally distributed number of children between the three diagnosis groups. Especially the group of children with DLD was small ($n = 13$), and these children also often scored lower in different tasks than children with ASD and ADHD. The recruitment of children depended on the parents' and children's interest in participating. It may be that children with a more severe symptom profile and their families were reluctant to volunteer and participate in the study. All these factors could have caused bias in our study.

Excluding the FEFA 2 test, all the emotion recognition tasks used were self-constructed. They have, however, high face-validity because the task types they represent are typically used when emotion recognition is assessed (e.g., Taylor *et al.* 2015). Additionally, although discerning emotions from voice had low reliability, emotion recognition from facial expressions had high reliability when FEFA 2, and tasks containing photographs and video clips were explored with Cronbach's alpha. By using results obtained from 106 TD children as a reference, we could, however, determine the typical performance in the tasks at each age level. However, due to time constraints during the data collection, we were not able to test the TD children's expressive vocabulary, rapid serial naming, and auditory and visual short-term memory skills. Instead, we had to base the delay variables of the clinical group on the test norms documented in the test manuals and age references published by Loukusa (2007). This is a clear limitation in our study.

Clinical implications

Despite the rather limited number of participants ($n = 50$), our findings suggest shared emotion recognition difficulties in children with ASD, ADHD and DLD. This means that the interventions these children need to improve their emotion recognition skills could also be similar across these diagnostic groups. Our study also revealed that language, ToM and working memory skills may be fundamental in the process of recognizing emotions. It is therefore important for clinicians to focus therapy on improving emotional vocabulary and ToM abilities, as well as keep in mind that these children may also have difficulties with working memory skills, which may further hamper emotion recognition skill development. However, focusing intervention only on linguistic or cognitive skills may not suffice; it is also important that therapy encompasses social–emotional skills in social situations and encourages generalization of newly learned emotion recognition skills to everyday life. The challenge is how exactly to help the children transfer emotion recognition skills to the peer relations and social situations. Research on this area has thus far been contradictory, at least concerning children with considerable challenges, such as those with ASD (e.g., Golan *et al.* 2008).

Conclusions

Overall, this study suggests that, compared with each other and to TD age peers, children with ASD, ADHD and DLD have similar difficulties in emotion recognition. The findings also included the predictive role of the first-order ToM, expressive vocabulary and working memory skills in facial expression recognition and matching facial expressions and tone of voice. Further research with larger samples and a wider set of predictive variables is needed to explore the shared basis of the emotion recognition skills in these disorders, since only a few studies focused on this topic before the present study.

Acknowledgements

The authors thank the children, their families and the professionals who participated in the study. The study was financed, in part, by the Social Security Institute of Finland (by a grant to the research group led by K.H.), the Foundation of Odd Fellows Barnfonden (to K.H.), the Finnish Association of Speech Therapists (to J.L.), the TOP Foundation (to J.L.) and the Research Foundation of the Mannerheim League for Child Welfare (to J.L.). All the financial support is gratefully acknowledged. ***Declaration of interest:*** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

AHONEN, T., TUOVINEN, S. and LEPPÄSAARI, T., 1999, *Nopean sarjallisen nimeämisen testi* [Rapid Serial Naming Test] (Jyväskylä: Haukkarannan koulu & Niilo Mäki Instituutti).

ALLOWAY, T., RAJENDRAN, G. and ARCHIBALD, L., 2009, Working memory in children with developmental disorders. *Journal of Learning Disabilities*, **42**, 372–382.

AMERICAN PSYCHIATRIC ASSOCIATION (APA), 2013, *Diagnostic and Statistical Manual of Mental Disorders (Fifth Edition)* (Washington, DC: APA).

BARON-COHEN, S., LESLIE, A. M. and FRITH, U., 1985, Does the autistic child have a 'Theory of Mind'? *Cognition*, **21**, 37–46.

BISHOP, D. V. M., 2010, Overlaps between autism and language impairment: phenomimicry or shared etiology? *Behavior Genetics*, **40**, 618–629.

BISHOP, D. V. M., SNOWLING, M. J., THOMPSON, P. A., GREENHALGH, T. and THE CATALISE-2 CONSORTIUM, 2017, Phase 2 of CATALISE: A multinational and multidisciplinary Delphi Consensus Study of problems with language development: Terminology. *Journal of Child Psychology and Psychiatry*, **58**, 1068–1080.

BORA, E. and PANTELIS, C., 2016, Meta-analysis of social cognition in attention-deficit/hyperactivity disorder (ADHD): comparison with healthy controls and autistic spectrum disorder. *Psychological Medicine*, **46**, 699–716.

BORHANI, K. and NEJATI, V., 2018, Emotional face recognition in individuals with attention-deficit/hyperactivity disorder: A review article. *Developmental Neuropsychology*, **4**, 256–277.

BOTTING, N. and CONTI-RAMSDEN, G., 2008, The role of language, social cognition, and social skill in the functional social outcomes of young adolescents with and without a history of SLI. *British Journal of Developmental Psychology*, **26**, 281–300.

BOUCHER, J., LEWIS, V. and COLLIS, G. M., 2000, Voice processing abilities in children with autism, children with specific language impairments, and young typically developing children. *Journal of Child Psychology and Psychiatry*, **41**, 847–857.

BÖLTE, S., FEINEIS-MATTHEWS, S., LEBER, S., DIERKS, T., HUBL, D. and POUSTKA, F., 2002, The development and evaluation of a computer-based program to test and to teach the recognition of facial affect. *International Journal of Circumpolar Health*, **61(Suppl. 2)**, 61–68.

BÖLTE, S., OLLIKAINEN, R., FEINEIS-MATTHEWS, S. and POUSTKA, F., 2013, FEFA 2. *Frankfurtin mallin mukainen tunteiden tunnistamisen testi ja harjoitteluohjelma* [The Frankfurt Test and Training of Facial Affect Recognition] (Stockholm: Center of Neurodevelopmental Disorders, Karolinska Institutet).

BÖLTE, S. and POUSTKA, F., 2003, The recognition of facial affect in autistic and schizophrenic subjects and their first-degree relatives. *Psychological Medicine*, **33**, 907–915.

DEMOPOULOS, C., HOPKINS, J. and DAVIS, A., 2013, A comparison of social cognitive profiles in children with autism spectrum disorders and attention-deficit/hyperactivity disorder: A matter of quantitative but not qualitative difference? *Journal of Autism and Developmental Disorders*, **43**, 1157–1170.

DENCKLA, M. B. and RUDEL, R., 1974, Rapid 'automatized' naming of pictures, objects, colors, and letters, and numbers by normal children. *Cortex*, **10**, 186–202.

DOHERTY, M. J., 2009, *Theory of Mind. How Children Understand Others' Thoughts and Feelings* (Hove: Psychology Press).

EVERS, K., STEYAERT, J., NOENS, I. and WAGEMANS, J., 2015, Reduced recognition of dynamic facial emotional expressions and emotion-specific response bias in children with an autism spectrum disorder. *Journal of Autism and Developmental Disorders*, **45**, 1774–1784.

GEURTS, H. M. and EMBRECHTS, M., 2008, Language Profiles in ASD, SLI, and ADHD. *Journal of Autism and Developmental Disorders*, **38**, 1931–1943.

GOLAN, O., BARON-COHEN, S. and GOLAN, Y., 2008, The 'Reading the Mind in Films' task [Child Version]: Complex emotion and mental state recognition in children with and without autism spectrum conditions. *Journal of Autism and Developmental Disorders*, **38**, 1534–1541.

GREEN, B. C., JOHNSON, K. A. and BRETHERTON, L., 2014, Review: Pragmatic language difficulties in children with hyperactivity and attention problems: an integrated review. *International Journal of Language and Communication Disorders*, **49**, 15–29.

HELLAND, W. A. and HELLAND, T., 2017, Emotional and behavioural needs in children with specific language impairment and in children with autism spectrum disorder: The importance of pragmatic language impairment. *Research in Developmental Disabilities*, **70**, 33–39.

KAPLAN, H., GOODGLASS, H. and WEINTRAUB, S., 1983, *Boston Naming Test* (Philadelphia, PA: Lea & Febiger).

KELTNER, D., OATLEY, K. and JENKINS, J. M., 2014, *Understanding Emotions (Third Edition)* (Hoboken, NJ: Wiley).

KIRK, S. A., MCCARTHY, J. J. and KIRK, W., 1968, *The Illinois Test of Psycholinguistic Abilities (Revised Edition)* (Urbana, IL: University of Illinois).

KUUSINEN, J. and BLÅFIELD, L., 1974, ITPA*:n teoria, ominaisuudet ja käyttö. Kasvatustieteen laitoksen julkaisuja 156* [Theory, Qualities and Use of ITPA] (Jyväskylän yliopisto: Kasvatustieteen tutkimuslaitos).

LAINE, M., KOIVUSELKÄ-SALLINEN, P., HÄNNINEN, R. and NIEMI, J., 1997, *Bostonin nimentätesti* [Boston Naming Test] (Helsinki: Psykologien Kustannus).

LEUNG, D., ORDQVIST, A., FALKMER, T. S., PARSONS, R. W. and FALKMER, M., 2013, Facial emotion recognition and visual search strategies of children with high functioning autism and Asperger syndrome. *Research in Autism Spectrum Disorders*, **7**, 833–844.

LOUCAS, T., CHARMAN, T., PICKLES, A., SIMONOFF, E., CHANDLER, S., MELDRUM, D. and BAIRD, G., 2008, Autistic symptomatology and language ability in autism spectrum disorder and specific language impairment. *Journal of Child Psychology and Psychiatry*, **49**, 1184–1192.

LOUKUSA, S., 2007, 3–9-VUOTIAIDEN LASTEN SUORIUTUMINEN BOSTONIN NIMENTÄTESTISTÄ [The performance of 3–9-year-old children in the Boston Naming Test]. *Puhe ja kieli*, **27**, 141–147.

LOUKUSA, S., MAKINEN, L., KUUSIKKO-GAUFFIN, S., EBELING, H. and MOILANEN, I., 2014, Theory of Mind and emotion recognition skills in children with specific language impairment, autism spectrum disorder and typical development: Group differences and connection to knowledge of grammatical morphology, word-finding abilities and verbal working memory. *International Journal of Language and Communication Disorders*, **49**, 498–507.

MOILANEN, I., 2011, *Autismikirjon häiriöt ja niiden samanaikaisuus ADHD:n kanssa* [Autism Spectrum Disorders and Comorbidity with ADHD] (Helsinki: Duodecim) (available at: http://www.terveyskirjasto.fi/terveyskirjasto/tk.koti?p_artikkeli=nix00918).

NATIONAL INSTITUTE FOR HEALTH AND WELFARE [TERVEYDEN JA HYVINVOINNIN LAITOS], 2011, *Third Edition of the Finnish Version of the International Statistical Classification of Diseases and Related Health Problems*. (Helsinki)

ONNISA, L., TRUZZI, A. and MA, X., 2018, Language development and disorders: Possible genes and environment interactions. *Research in Developmental Disabilities*, **82**, 132–146.

Perner, J. and Wimmer, H., 1985, 'John thinks that Mary thinks that ...': Attribution of second-order beliefs by 5- to 10-year-old children. *Journal of Experimental Child Psychology*, **39**, 437–471.

Rapin, I. and Allen, D. A., 1988, Syndromes in developmental dysphasia and adult aphasia. In F. Plum (ed.), *Language, Communication and the Brain* (New York, NY: Raven), pp. 57–75.

Rommelse, N. N., Franke, B., Geurts, H. M., Hartman, C. A. and Buitelaar, J. K., 2010, Shared heritability of attention-deficit/hyperactivity disorder and autism spectrum disorder. *European Child and Adolescent Psychiatry*, **19**, 281–295.

Simpson, N. H., Ceroni, F., Reader, R. H., Covill, L. E., Knight, J. C.; Sli Consortium, Hennessy, E. R., Bolton, P. F., Conti-Ramsden, G., O'hare, A., Baird, G., Fisher, S. E. and Newbury, D.F., 2015, Genome-wide analysis identifies a role for common copy number variants in specific language impairment. *European Journal of Human Genetics*, **23**, 1370–1377.

Sinzig, J., Morsch, D. and Lehmkuhl, G., 2008, Do hyperactivity, impulsivity and inattention have an impact on the ability of facial affect recognition in children with autism and ADHD? *European Child and Adolescent Psychiatry*, **17**, 63–72.

Smoller, J. W., Craddock, N., Kendler, K., Lee, P. H., Neale, B. M., Nurnberger, J. I., Ripke, S., Santangelo, S., Sullivan, P. F., Perlis, R. H., Purcell, S. M., Fanous, A. and Landén, M., 2013, Identification of risk loci with shared effects on five major psychiatric disorders: a genome-wide analysis. *Lancet*, **381**, 1371–1379.

Spackman, M., Fujiki, M., Brinton, B., Nelson, D. and Allen, J., 2005, The ability of children with language impairment to recognize emotion conveyed by facial expression and music. *Communication Disorders Quarterly*, **26**, 131–143.

Taylor, L. J., Maybery, M. T., Grayndler, L. and Whitehouse, A. J. O, 2015, Evidence for shared deficits in identifying emotions from faces and from voices in autism spectrum disorders and specific language impairment. *International Journal of Language and Communication Disorders*, **50**, 452–466.

Waddington, F., Hartman, C., De Bruijn, Y., Lappenschaar, M., Oerlemans, A., Buitelaar, J., Franke, B. and Rommelse, N., 2018, Visual and auditory emotion recognition problems as familial cross-disorder phenomenon in ASD and ADHD. *European Neuropsychopharmacology*, **28**, 994–1005.

World Health Organization (WHO), 1992, *The ICD-10 Classification of Mental and Behavioural Disorders: Clinical Descriptions and Diagnostic Guidelines* (Geneva: WHO).