Early language competence, but not general cognitive ability, predicts children's recognition of emotion from facial and vocal cues (#45198)

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Early language competence, but not general cognitive ability, predicts children's recognition of emotion from facial and vocal cues

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The ability to accurately identify and label emotions in the self and others is crucial for successful social interactions and good mental health. In the current study we tested the longitudinal relationship between early language skills and recognition of facial and vocal emotion cues in a representative UK population cohort with diverse language and cognitive skills (N = 369), including a large sample of children that met criteria for Developmental Language Disorder (DLD, N = 97). Language skills, but not non-verbal cognitive ability, at age 5-6 predicted emotion recognition at age 10-12. Children that met the criteria for DLD showed a large deficit in recognition of facial and vocal emotion cues. The results highlight the importance of language in supporting identification of emotions from non-verbal cues. Impairments in emotion identification may be one mechanism by which language disorder in early childhood predisposes children to later adverse social and mental health outcomes.

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Running head: Language competence predicts emotion recognition

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Abstract

The ability to accurately identify and label emotions in the self and others is crucial for successful social interactions and good mental health. In the current study we tested the longitudinal relationship between early language skills and recognition of facial and vocal emotion cues in a representative UK population cohort with diverse language and cognitive skills (N = 369), including a large sample of children that met criteria for Developmental Language Disorder (DLD, N = 97). Language skills, but not non-verbal cognitive ability, at age 5-6 predicted emotion recognition at age 10-12. Children that met the criteria for DLD showed a large deficit in recognition of facial and vocal emotion cues. The results highlight the importance of language in supporting identification of emotions from non-verbal cues. Impairments in emotion identification may be one mechanism by which language disorder in early childhood predisposes children to later adverse social and mental health outcomes.

Keywords: developmental language disorder, emotion recognition, facial expression, vocal expression, longitudinal cohort study, language development.

Introduction

Recognition of emotional cues, such as facial and verbal expressions, is an important social skill. It provides us with information about other people's internal emotional states and helps us to interpret and predict their behaviour. Children have typically acquired the vocabulary for basic emotions by 4-6 years of age (Baron-Cohen, Golan, Wheelwright, Granader, & Hill, 2010; Ridgeway, Waters, & Kuczaj, 1985), but accuracy in identifying non-verbal emotional cues continues to improve into late adolescence (Grosbras, Ross, & Belin, 2018; Herba & Phillips, 2004; Rodger, Vizioli, Ouyang, & Caldara, 2015). Accurate emotion identification has been linked to positive outcomes later in development, including academic success (Denham et al., 2012; Izard et al., 2001), social integration (Sette, Spinrad, & Baumgartner, 2017) and good mental health (Ciarrochi, Scott, Deane, & Heaven, 2003).

A critical part of learning to identify emotions is developing emotional concepts that align precisely with the emotional concepts held by other people. The Theory of Constructed Emotion (TCE; Gendron & Barrett, 2018) proposes that language is crucial for acquiring nuanced emotional concepts. Verbal labels provide a framework to organise highly variable input from the environment into coherent emotion concepts (Gendron & Barrett, 2018; Lindquist, 2017). Critically, the TCE suggests that the role of language in supporting emotion recognition goes beyond acquisition of emotion vocabulary. Precise conceptual alignment is achieved through communication with others. If an individual has less opportunity to learn about emotion concepts through language, their conceptual alignment would be compromised, which would lead to less accurate emotion identification. Previous research has shown that parent-child discourse about emotions predicts children's emotion identification accuracy months later (Dunn, Brown, Slomkowski, Tesla, & Youngblade, 1991), consistent with the theory that language aids learning about emotions.

In the current study, we test the hypothesis that language supports development of accurate emotion identification by studying a population that have reduced opportunity to learn about emotion concepts through language. Children with Developmental Language Disorder (DLD; previously known as Specific Language Impairment; Bishop, Snowling, Thompson, Greenhalgh, & The Catalise Consortium, 2017) have difficulties with receptive and/or expressive language that cannot be explained by a sensory deficit or neurological impairments (American Psychiatric Association, 2013). Unlike children with autism spectrum disorders (ASD), children with DLD do not have primary social or emotional difficulties, so any problems with emotion recognition are likely to be a consequence of difficulties acquiring language. If language is necessary for emotion conceptual alignment, children with DLD should have persistent difficulties with emotion identification, due to reduced opportunity to learn about emotion concepts through language.

A few small studies have found that school-aged children with DLD have difficulty labelling and categorising facial (Bakopoulou & Dockrell, 2016; Taylor, Maybery, Grayndler, & Whitehouse, 2015) and verbal (Boucher, Lewis, & Collis, 2000; Taylor et al., 2015) emotional expressions. However, other studies have reported contradictory results (Creusere, Alt, & Plante, 2004; Loukusa, Mäkinen, Kuusikko-Gauffin, Ebeling, & Moilanen, 2014; Trauner, Ballantyne, Chase, & Tallal, 1993). This equivocal evidence is likely due to variable diagnostic criteria, the heterogeneity of the tasks used, and reduced statistical power due to the small sample sizes. The estimated effect size for emotion recognition deficits in ASD, which we would assume to be larger than the size of any deficit in DLD (due to the primary of their social-emotional difficulties), is estimated to be 0.41 (Uljarevic & Hamilton, 2013). Power calculation suggests a sample size of 135 participants in each group is needed to reliably detect an effect of this size (Uljarevic & Hamilton, 2013). Therefore, much larger studies are required to determine whether children with DLD do have difficulties with emotion identification.

A number of cross-sectional studies in the typically developing population have found associations between language competence and the ability to label and match emotion emotional facial expressions in early childhood (Beck, Kumschick, Eid, & Klann-Delius, 2012; Pons, Lawson, Harris, & De Rosnay, 2003; Rosenqvist, Lahti-Nuuttila, Laasonen, & Korkman, 2014), although other studies have failed to find this relationship (Herba, Landau, Russell, Ecker, & Phillips, 2006; Herba & Phillips, 2004). Concurrent relationships between emotion recognition performance and language competence in early childhood may be the result of children not having the vocabulary to meet the language demands in the task. Stronger support for a role of language in refining emotional concepts would come from demonstrating a longitudinal relationship between language competence in early childhood and later accuracy in applying labels to emotion cues, at an age when children have acquired basic emotion vocabulary.

In the current study, we use data from a well-characterised longitudinal population cohort that includes children with the full spectrum of language abilities, including a large number of children with DLD. We tested the relationship between early language competence (age 5-6) and the ability to match facial and vocal emotion cues to basic emotion labels in middle childhood (age 10-12) controlling for children's non-verbal cognitive ability. Additionally, we tested whether emotion recognition is poorer in children that meet the criteria for DLD at age 5-6, compared to children with typical language. The analysis plan for this study was preregistered on the Open Science Framework (osf.io/pwcms).

Materials and Methods

Sample description

Data are taken from the Surrey Communication and Language in Education Study (SCALES). This study has followed a cohort of children who entered state-maintained schools in the county of Surrey in the United Kingdom in September 2011. Language and communication skills were assessed at school entry via a teacher report questionnaire (Children's Communication Checklist-Short; CCC-S; Norbury et al., 2016). Based on screening, children were classified as having (1) no phrase speech (NPS) (2) high risk for DLD (3) low risk for DLD. Children were classified NPS if their teacher responded 'no' to the question 'is the child combining words into phrases or sentences?' The cut-off between high and low risk status was based on age and sex specific cut- on the CCC-S derived from the entire screened population (N=7267) Norbury et al. 2016 for details).

Stratified random sampling identified a subset of 636 children from the screened population who were invited to take part in in-depth assessments. Children attending special schools for children with severe intellectual or physical disability, and/or English as a second language were excluded from sampling. All remaining childre ntified as being NPS (N=48) were invited, as were 233 low risk and 355 high risk children. 529 monolingual children were assessed in Year 1, an of these were assessed in Year 6. This final assessment included the emotion recognition tasks.

Language assessments in Year 1 were used to calculate composite scores for expressive language, receptive language, vocabulary, grammar and narrative skills (Norbury et al., 2016). Children were identified as meeting Developmental Language Disorder (DLD) if they scored -

1.5 SD on at least 2 out of 5 of these composite scores in Year 1. Scores from block design and matrix reasoning (WPPSI-III; Wechsler, 2003) in Year 1 were used to calculate a non-verbal IQ composite. This was used to identify children with intellectual disability, defined as a non-verbal IQ composite score of less than -2 SD. Children that met DLD criteria in Year 1 were additionally classified as having DLD with no known associated biomedical condition or DLD with a known associated biomedical condition (hereafter termed LD+). Inclusion criteria for 'known associated biomedical condition' was intellectual disability based on non-verbal IQ assessments and/or parent/teacher reported diagnosis of an associated condition such as autism (Norbury et al., 2016).

Consent

Consent procedures and study protocol were developed in consultation with Surrey County Council and approved by the Royal Holloway Ethics Committee (in where the study started) in Year 1 and the UCL Research Ethics Committee in Year 6 (9733/002). Informed consent was collected from parents before in-depth assessments in Year 1 and Year 6. Informed assent was collected from children prior to the Year 6 assessment. Children were given certificates and small prizes at the end of each assessment session.

Sample size and power calculations

We conducted a priori sensitivity analyses in G-Power based on a sample size estimate of 399 participants (assuming a retention rate of 80% from previous assessment time-point in Year 3). Sensitivity analysis suggested we would have 90% power to detect small (r = .15) associations between language and emotion recognition accuracy in the whole sample (Cohen, 2013). We also conducted a sensitivity analysis for assessing the group difference between DLD group and the rest of the sample. Assuming equal attrition we estimated that we would have 103 children in Year 6 that had met the DLD criteria in Year 1, including 70 with DLD with no additional diagnosis. Sensitivity analysis suggest that this would provide 90% power to detect a small-medium group differences (d = 0.34 for comparison with full DLD group and d = 0.38 for comparison excluding children with DLD with known origin) (Cohen, 2013).

Assessment procedure

Year 1 Language

In Year 1 children completed 6 tasks to assess receptive and expressive language skills. These were; (1-2) Receptive/Expressive One word Picture Vocabulary Test (R/EOWPVT-4; Martin & Brownell, 2000), (3) Test of Reception of Grammar – Short Form (TROG-S), (4) School-Age Sentence Imitation Test (SASIT E32 6) Assessment of Comprehension and Expression 6-11 (ACE 6-11; Adams et al., 2001). We combined scores on all of these tasks into a single language composite score by averaging the Z-scores.

Year 1 Non-verbal IQ assessment

In Year 1 children completed two test of non-verbal IQ (NVIQ); (1) Wechsler Preschool and Primary Scale of Intelligence 3rd edition Block Design and (2) Matrix Reasoning subtests (WPPSI-III; Wechsler, 2003). Performance on these two tasks has been combined to create a NVIQ composite score (Norbury et al., 2016).

Year 6 Emotion recognition

In Year 6 children completed two emotion recognition tasks; one to measure recognition of emotion from faces and one to measure emotion recognition from voices. Each task consisted of

60 trials in which children were presented with photos of faces or recordings of vocal sounds corresponding to one of 6 emotions (happy, sad, angry, surprised, scared and disgusted). For the facial expression task, stimuli were photos of 10 actors (5 female and 5 male) selected from the Radboud Faces Database (Langner et al., 2010). For the vocal expression task, non-verbal sound stimuli were selected from a validated set (Sauter, Eisner, Calder, & Scott, 2010) that have previously been used in research with adults with developmental disorders (Jones et al., 2011). The sounds are made by 4 actors (2 male and 2 female) that contribute one or more vocal expression to each emotion category. In both tasks, participants were shown a fixation cross for 500ms, followed by face stimuli for 2 seconds or the audio clip accompanied by a cartoon image of a listening man, followed by the 6 emotion labels presented in a circular formation on the screen. The labels remained until the participant made a response. The order of the emotion labels on the screen was randomised between participants and tasks, but kept the same between trials for each participant. Total accuracy scores were calculated out of 60 for each task separately.

Before completing the task, we checked children's understanding of the 6 emotion words by asking them to read the labels aloud and describe or imitate that emotion. If the child was unable to describe or imitate one or more of the emotions, the assessment was terminated as it was assumed they did not have the basic emotion vocabulary. A very small number of children were not able to read the labels but could describe or imitate the emotion when the word was said aloud. For these children the researcher asked them give their response verbally during the task and inputted their responses for them.

Analysis plan

Standardisation of scores

Test scores from each of the six language assessments and the two NVIQ assessments in Year 1 were standardised using the LMS method (Vamvakas, Norbury, Vitoratou, Gooch, & Pickles, 2019). LMS is a method of standardisation based on the Box-Cox transformation that coverts scale raw scores to normality. The resulting scores reflect standardised scores adjusted for age, with a mean of 0 and a standard deviation of 1. We planned to standardise emotion recognition scores using the same method but this was not necessary as performance was not correlated with age in our sample (faces $r = .05$, $p = .37$; voices $r = .002$, $p = .97$).

Sampling weights and missing data

Sampling weights were included in all analyses to account for study design and any bias in attrition. This adjustment means that estimates are representative of the screened sample of 6,459 mono-lingual children in state-maintained schools. Sampling weights were produced by multiplying the inverse of the predicted probability of two logistic regression models that predict inclusion in the sample. The first regression model estimates a child's likelihood of being initially invited into the study. This was fitted to the entire population of 6,459 mono-lingual children in mainstream schools that were screened at school entry. The covariates in this model are those that determined selection into the study due to the stratified sampling method. These are total number of children assessed per school, and whether a child was identified as at risk for DLD based on CCC-S teacher ratings (86th centile or above for sex and age group). The second regression model was fitted to the 636 children invited into the study. This model includes any variable that might be predictive of inclusion in the sample included in the current analysis. This included individual characteristics such as sex, income deprivation score, special education needs, free school meals, English as additional language, CCC-2 score, language in Year 1, season of birth, SDQ total difficulties, and school characteristics such as number of pupils on role, percentage of girls, percentage with SEN, and percentage with free school meals. These variables were tested in a stepwise elimination process and included in the model if they predict inclusion above a cut-off point of .2.

Statistical analysis

Statistical analyses were conducted in R version 3.5.3 and M-Plus. Structural Equation Models (SEM) were built under robust maximum likelihood estimator which is robust to deviations from normality. To test the hypothesis that language competence in Year 1 predicts emotion recognition from faces and voices in Year 6, path analysis was used to model the association between children's composite language scores in Year 1 and their scores on the facial expression and vocal expressions tasks in Year 6. Additionally, because one pervious study had suggested that children with DLD may be more impaired in recognition of emotion cues from voices rather than faces (Trauner, Ballantyne, Chase, & Tallal, 1993) we compared the strength of the pathways between language and performance on the facial expression task and vocal expression task using Wald test of parameter constraints. Finally, we then entered Year 1 NVIQ composite into the model to assess whether language scores continue to predict emotion recognition after accounting for variation in non-verbal cognitive ability.

We then compared children in the DLD group to the rest of the sample on total accuracy from the emotion recognition tasks separately. We did not control for NVIQ in this analysis because low NVIQ is not an exclusion criteria for DLD (Bishop, Snowling, Thompson, Greenhalgh, & The Catalise Consortium, 2017) and language severity is associated with NVIQ (Norbury et al., 2017). This means 'controlling' for group differences in NVIQ would 'control' for relevant and non-random differences between the two groups (Dennis et al. 2009). We conducted this analysis both with and without removing children with additional diagnoses, to determine if there was still a group difference after removing children with co-occurring conditions that have also been associated with problems with emotion recognition (e.g. autism and/or severe intellectual disability).

Results

Participants

Of the 384 participants were seen for assessment in Year 6, 362 (including 67 with DLD and 29 with LD+ additional diagnoses) completed the facial emotion recognition task and 359 (63 with DLD and 27 with LD+ additional diagnoses) completed the vocal emotion recognition task. 369 completed at least one task (67 with DLD and 30 with LD+ additional diagnoses) so were included in the analysis. Of the 15 children that did not complete either task, six met criteria for language disorder in Year 1. These children did not complete the task because they did not have the basic emotion vocabulary or were otherwise unable to engage in the task. The other nine children did not have DLD did not complete the tasks due to technical issues. Table 1 provides descriptive statistics for all variables for the total sample, and DLD, LD+, and typical language groups separately.

Attrition was slightly higher than we had anticipated when we conducted our a priori sensitivity analysis. However, our achieved sample size still ga 90% power to detect small associations between language and emotion recognition ($r = 0.15$). We also still had 90% power to detect small-medium size group differences in emotion recognition accuracy between the DLD group and typical language group ($d = 0.35$), even after excluding those with LD+ additional diagnoses ($d = 0.41$).

Does early language competence predict later emotion recognition accuracy?

Path analysis supported our prediction that early language competence is positively associated with emotion recognition ability in late childhood. There were moderate prospective relationships between language competence in Year 1 and emotion recognition from vocal expressions (β = .40, S.E = .06, 95% CI [.28,.51]) and facial expressions (β =.42, S.E = .06, 95% CI [.30,.55]) in Year 6.

The relationship between language and emotion recognition was similar for faces and voices. Wald's test of parameter constraints did not provide evidence for a difference in path strengths ($X^2(1)$ =2.51, p = .11). We had planned on combining the two emotion recognition scores into a single composite score if there was no evidence for a difference in path strengths. However, the correlation between the two outcomes estimated in the model was not sufficient to justify this (r = .37, S.E = .06, 95% CI [.25, .50]).

When NVIQ in Year 1 was entered into the path model as a predictor, the relationships between language and performance on the two emotion recognition tasks remained, and there was no statistical evidence for a prospective relationship between NVIQ and performance on either emotion recognition task (see Fig. 1 for the standardised regression coefficients and confidence intervals for these paths). These results support our hypothesis that early language is positively associated with emotion recognition accuracy, even after adjustment for non-verbal IQ.

Do children with DLD have poorer emotion recognition skills than their peers with typical language?

Figure 2 illustrates the distributions of raw accuracy scores on the facial and vocal emotion recognition task for children diagnosed with DLD and children with language in the typical range. Weighted t-tests provided clear statistical evidence for a large group difference in recognition of emotions from faces; $t(360) = 4.06$, $p < .001$, $d = .90$, and voices $t(353) = 4.24$, $p < .001$, $d = 0.89$, between these groups. When children with LD+ additional diagnoses were removed, the effect sizes reduced slightly but there was still evidence for a medium-large group difference for recognition of emotion from faces; $t(331) = 2.72$, $p = .007$, $d = .72$, and voices; $t(326) = 2.87$, $p < .001$, $d = .78$. These findings support our hypothesis that children who meet the criteria for DLD in early childhood are poorer at recognising emotions from both faces and voices in late childhood than their peers with typical language.

Do children with DLD make similar errors in emotion recognition tasks to their peers with typical language?

In order to explore possible differences in the kinds of errors made by children with DLD and those without DLD, we created confusion matrices for each task for each group of children (Fig. 3.). From these it can be seen that in general the pattern of errors is very similar across the two groups. The most commonly misidentified emotion in the facial emotion recognition task was disgust in the DLD group and fear in the typical language group and the least commonly misidentified emotion was happiness in both groups. For the vocal emotion recognition task, the most commonly misidentified emotion in both groups was surprised and the least commonly misidentified emotion was happiness in the DLD group and disgust in the typical language group.

Discussion

In the present study we examined the prospective relationship between language competence in early childhood and identification of non-verbal emotion cues in middle childhood in a large population-derived cohort of children with diverse language and cognitive skills. We found evidence for a moderate relationship between language competence at age 5-6 and recognition of facial and vocal emotional cues at age 10-12. This relationship held when adjusting for non-verbal cognitive ability, suggesting language selectively predicts emotion recognition ability in middle childhood. Furthermore, we found that children with DLD, who are less able to learn about emotions through language, have a large deficit in emotion recognition ability. This is the first longitudinal evidence to support the hypothesis from the TCE that language competence plays a role in supporting accurate identification non-verbal emotion cues (Gendron & Barrett, 2018).

These results help clarify contradictory literature on whether children with DLD have deficits in emotion recognition (Bakopoulou & Dockrell, 2016; Boucher, Lewis, & Collis, 2000; Creusere, Alt, & Plante, 2004; Loukusa, Mäkinen, Kuusikko-Gauffin, Ebeling, & Moilanen, 2014; Taylor, Maybery, Grayndler, & Whitehouse, 2015; Trauner et al., 1993). The majority of previous studies have been small ($N < 20$ children with DLD) and have therefore lacked the statistical power to detect the expected medium-small effect size (Uljarevic & Hamilton, 2013). Ninety-seven children in our cohort that met the DSM criteria for DLD when they were 5-6 years old, based on rigorous linguistic and cognitive testing, completed at least one emotion recognition task in Year 6, giving us sufficient statistical power. We found strong evidence for a large difference in emotion recognition ability at age 10-12 between those that met the criteria for DLD at age 5-6 compared to those with language in the typical range at age 5-6. When children with other diagnoses that associate with both language and emotion recognition difficulties were excluded from the DLD group (e.g. autism or intellectual disability), the group difference attenuated somewhat, but the statistical evidence for differences between children with DLD and their peers remained strong. These findings provide the best evidence to date that children with

DLD have emotion recognition deficits, and that these are directly linked to language proficiency.

Our emotion recognition task was verbal in the sense that children had to match non-verbal emotion cues to verbal labels. It could therefore be argued that the verbal demands of the task explain the relationship between language competence and emotion recognition performance. However, the labels were basic emotion words that are highly frequent and well within the vocabulary range of children aged 10-12 (Baron-Cohen et al., 2010), even the vast majority of those with DLD. We checked that children understood the emotion words before completing the assessment. A very small number of children with DLD (N=6) lacked the vocabulary to engage in the task, so were not included in the study. Non-verbal tasks, such as a facial expression matching task (Taylor et al., 2015), can be completed using visual features alone, without any comprehension of the underlying emotion and so do not truly test emotion identification. We argue that performance on an emotion labelling is associated with early language competence not just because it involves a verbal label, but because language is involved in developing nuanced emotion concepts through communication with others throughout childhood (Gendron & Barrett, 2018).

The ability to recognise and label emotions in the self and others is an important component of social problem solving. The finding that this ability is compromised in DLD may elucidate why children with DLD are at increased risk of internalising, externalising and ADHD symptoms (Yew & O'Kearney, 2013). The causal pathway between DLD and poor mental health outcomes is unclear, but one possibility is that language problems interfere with aspects of social-emotional processing (such as emotion concept development), which in turn leads to negative social, emotional and mental health outcomes. Im-Bolter, Cohen, and Farnia (2013) found that adolescents referred to mental health services had poorer structural and figural language than peers recruited from the community and were poorer at social problem solving. The findings in the current study raise the possibility that emotion identification may be one pathway in which poor language in early childhood compromises social functioning and mental health in children with and without DLD.

Although our findings are consistent with a causal relationship between language competence and emotion recognition, they cannot provide proof of causality. One way to investigate whether this relationship is truly causal would be to test whether interventions aimed at improving language have positive, cascading effects on emotion recognition skills later in development. To date there has been one preliminary study (N= 208) investigating whether a nine-week intervention focusing specifically on improving language related to emotion through storybooks improves other emotional skills in typically developing 7-9 year old children. The intervention group showed improvements in emotional vocabulary, emotion knowledge and recognition of masked emotions from vignettes compared to a 'treatment as usual' control group straight after the intervention (β = 1.05-1.32; Kumschick et al., 2014). Future research is needed to determine whether a similar intervention could improve emotion recognition and other social-emotional competencies in children with and without DLD.

Conclusions

In conclusion, this study provides the first longitudinal evidence that early language skills specifically predict later emotion recognition from both facial and vocal cues. These findings support the hypothesis that language plays a role in supporting emotion identification (Barrett, Lindquist, & Gendron, 2007; Gendron & Barrett, 2018; Lindquist, 2017). Children with DLD are therefore especially vulnerable to difficulties recognising their own and others' emotional states. We propose that this deficit may be one causal mechanism that underpins the reported relationship between early language skills and later adverse mental health.

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Open Practices Statement

The hypotheses and analysis plan for this study was preregistered on the Open Science Framework (osf.io/pwcms). Twelve participant's parents did not consent to Open Data sharing so we are unable to share the full dataset. However, our code and a dataset with these 12 participants removed is available on the OSF page for this study.

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Table 1(on next page)

Descriptive statistics for the full sample and each language group separately.

Language and NVIQ are standard scores based on population norms estimated using sample weights. Emotion recognition scores are raw total accuracy scores on each task.

Table 1:

Descriptive statistics for the full sample and each language group separately.

Language and NVIQ are standard scores based on population norms estimated using sample weights. Emotion recognition scores are raw total accuracy scores on each task.

	Full sample N = 369	Typical language N = 272	DLD N = 67	LD+ N = 30
	Mean (SD)	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
Age Year 1 (Months)	72 (4.69)	72 (4.84)	71 (4.05)	74 (4.06)
Age Year 6 (Months)	134 (4.06)	134 (4.04)	133 (4.29)	135 (3.69)
Male (%)	50.14	47.43	55.22	63.33
Language composite Year 1	-0.59 (1.06)	-0.09 (0.85)	-1.78 (0.49)	-2.50 (0.67)
NVIQ composite Year 1	-0.39 (1.07)	-0.13 (0.98)	-0.83 (0.65)	-1.81 (1.19)
ER faces Year 6[a]	0.76 (0.12)	0.79 (0.10)	0.71 (0.14)	0.61 (0.13)
ER voices Year 6[b]	0.75 (0.11)	0.78 (0.08)	0.71 (0.12)	0.59 (0.16)

NVIQ = non-verbal IQ; ER = Emotion recognition

a Based on 362 total, 272 TL, 67 DLD, 29 LD+

b Based on 359 total, 278 TL, 63 DLD, 30 LD+

Figure 1

Path model showing prospective relationships from language (Lang) and non-verbal IQ (NVIQ) in Year 1 to emotion recognition from faces (ER faces) and voices (ER voices) in Year 6.

Significant paths are solid lines while insignificant paths are dashed line Significant paths are solid lines while insignificant paths are dashed lines.

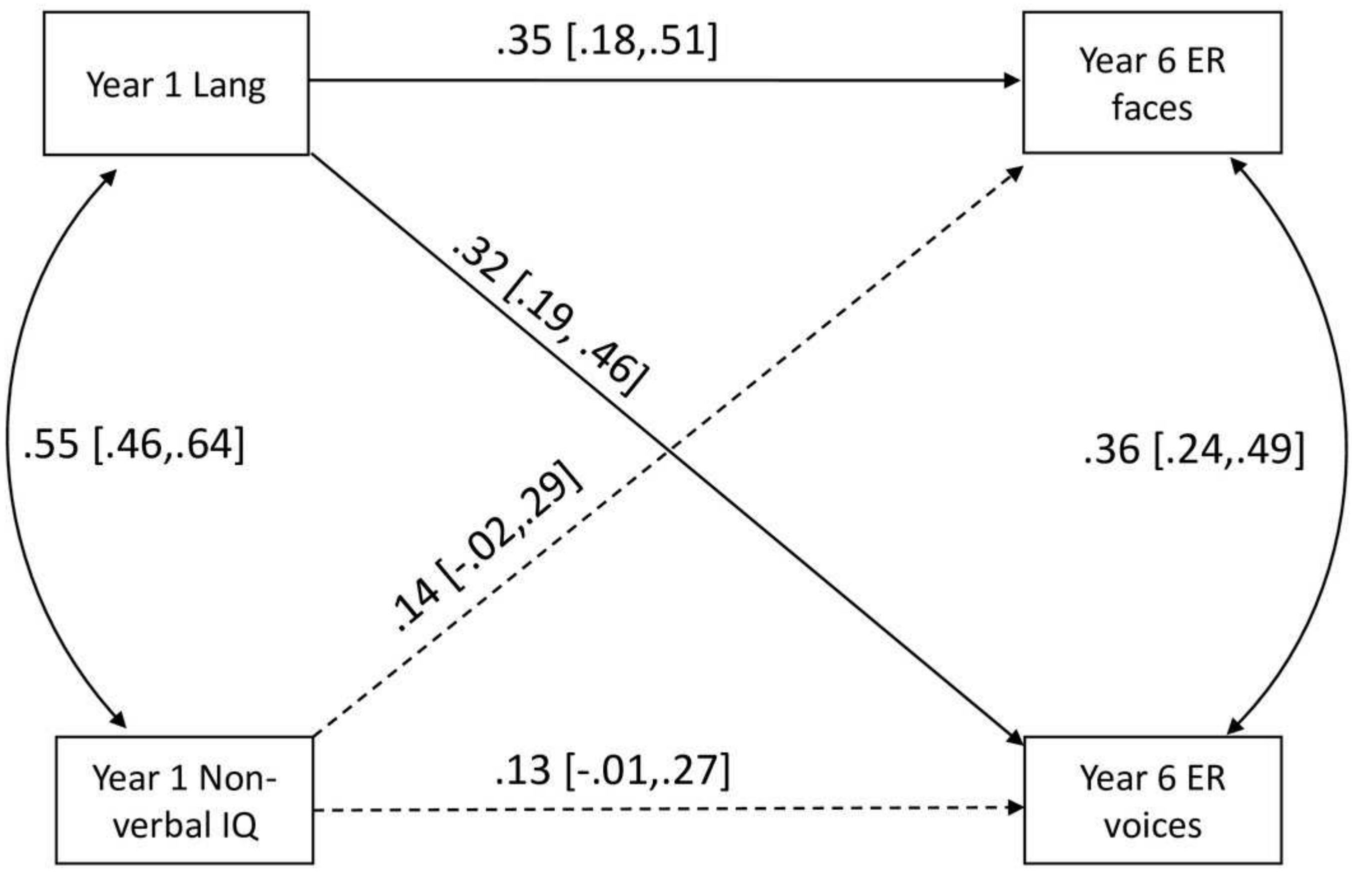


Figure 2

Pirate plot showing distribution of total scores on (A) the vocal emotion recognition task and (B) the facial emotion recognition task for group with DLD and the typically language group.

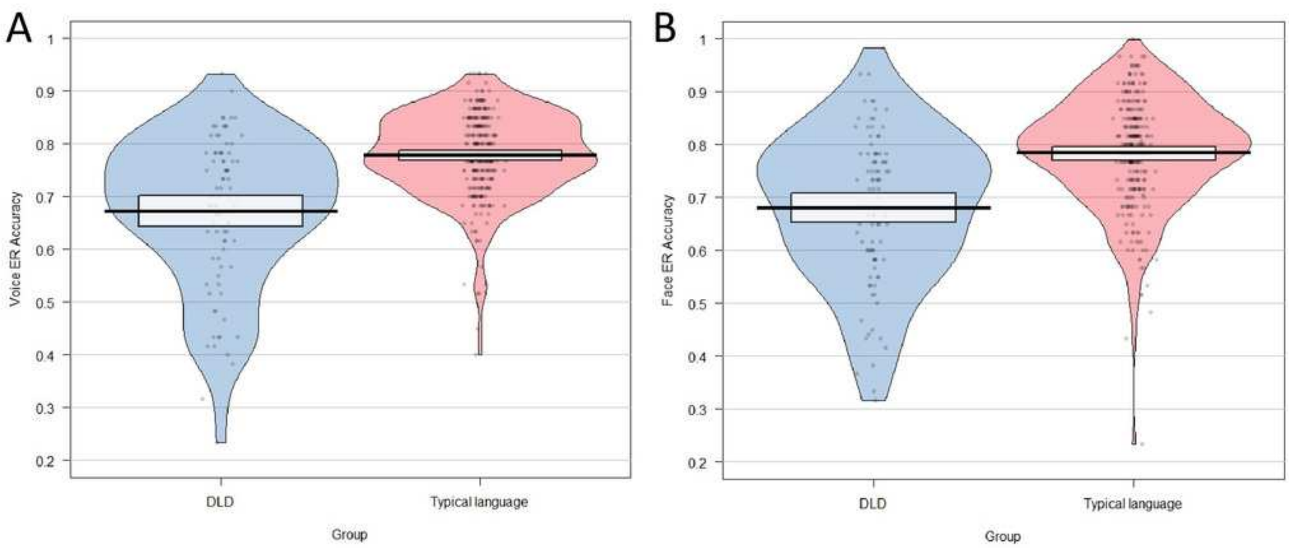
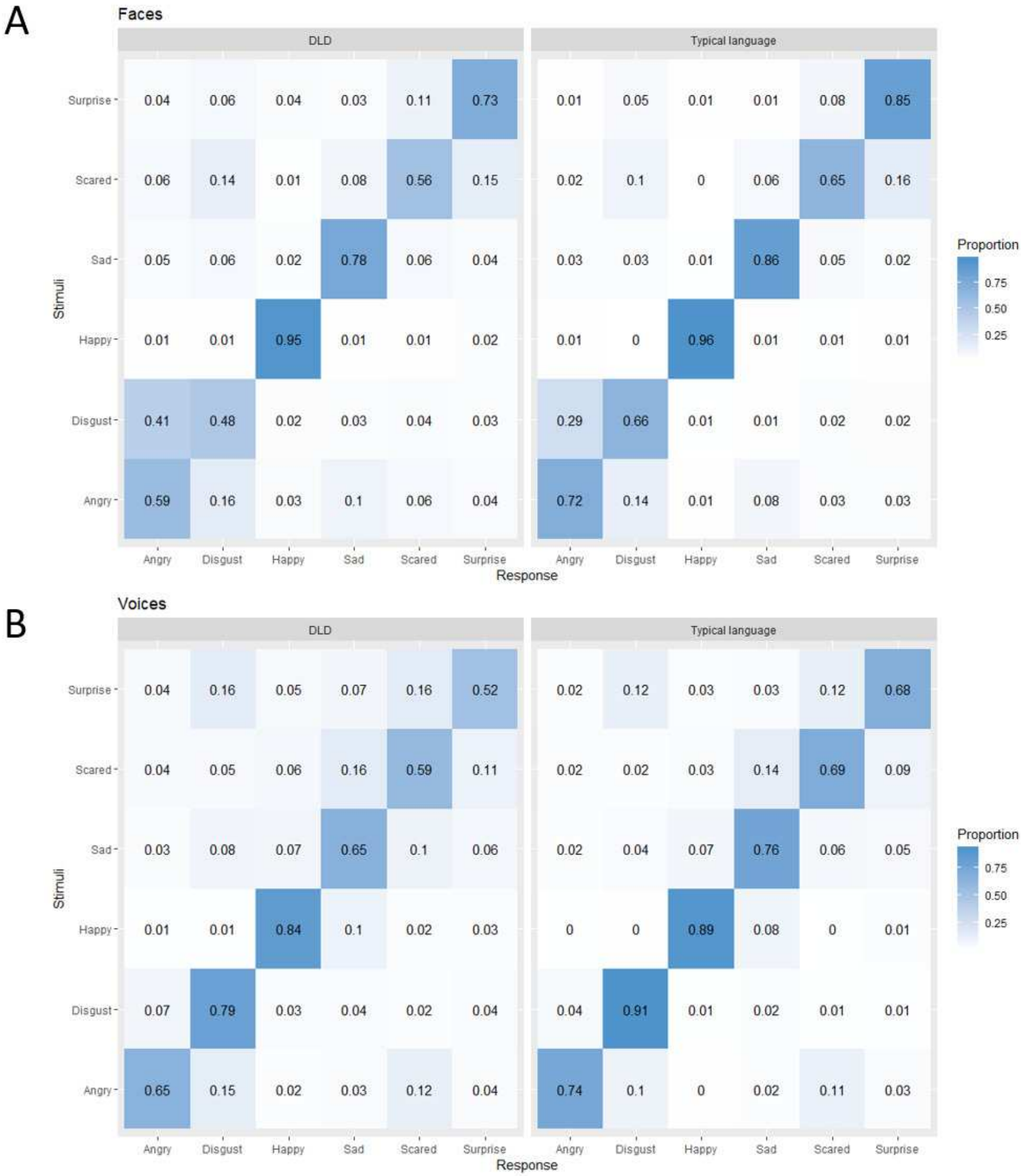


Figure 3

Confusion matrices showing proportion of responses in each category for each presented emotion separately for group with DLD (left) and with typical language (right) for (a) faces and (b) voices.


A
Faces
DLD
Typical language
Surprise
Scared
Sad
Happy
Disgust
Angry
Stimuli
Angry Disgust Happy Sad Scared Surprise
Response
Proportion
0.75
0.50
0.25
B
Voices