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Title:

Exploring different aspects of emotion understanding in adults with Down Syndrome

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HIGHLIGHTS

- Language, non-verbal reasoning (NVR) and working memory (WM) are related to emotion understanding skills.
- Some aspects of emotion understanding remain unexplored in the adult population with Down Syndrome (DS).
- Adults with DS and neurotypical children completed the Test of Emotion Comprehension.
- Adults with DS showed lower emotion understanding and a different pattern of errors.
- Language, WM and NVR predicted different aspects of emotion understanding.

Abstract

Background: Adults with Down Syndrome (DS) present difficulties in emotion understanding, although research has mainly focused on emotion recognition (external aspects), and little is known about their performance in other complex components (mental and reflective aspects).

Aims: This study aims to examine different aspects of emotion understanding in adults with DS, including a codification of their error pattern, and also to determine the association with other variables that are commonly impaired in adults with DS.

Methods and Procedures: Twenty-two adults with DS and twenty-two children with typical development (TD) matched for vocabulary level were assessed with the Test of Emotion Comprehension (TEC), along with other non-verbal reasoning (NVR), structural language and working memory (WM) tasks.

Outcomes and Results: Adults with DS showed lower emotion competence than children with TD in different components of the TEC, and also a different pattern of errors was observed. Structural language, NVR and WM predicted distinct emotion understanding skills in different ways.

Conclusions and Implications: It is important to plan interventions aimed at improving particular aspects of emotion understanding skills for adults with DS, taking into account the different components, the type of error and the different cognitive and linguistic skills involved in each emotion understanding skill.

What this paper adds

Few papers examine the emotion understanding of adults with Down Syndrome (DS), since their sociability usually masks the real problems they have when it comes to empathizing with other people. In addition, most empirical evidence comes from children with DS. Although facial recognition of emotions or discrimination between them has been studied, more complex levels related to mental and reflective processes have not been analysed. Furthermore, the pattern of errors that they make and the association with different cognitive and linguistic variables remain unexplored. This study adds empirical knowledge about the

overall level of emotion understanding of adults with DS in nine components assessed with a standardized test (the Test of Emotion Comprehension, TEC), and it is compared to the level of verbal age-matched children with TD. The study also examines the type of mistake they make when these occur, and what linguistic and cognitive factors are related to their level of emotion understanding.

Keywords: Down syndrome; adults; emotion understanding; structural language; working memory; non-verbal reasoning.

Funding

This work was supported by a grant funded by Universitat Jaume I of Castelló (UJI-A2016-12).

Ethical approval

All procedures included in studies involving human participants were performed in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study. Approval from the local government and the ethics committee of the Universitat Jaume I of Castelló were obtained. Schools and parents/guardians also gave their informed consent.

1. Introduction

Emotion understanding could be defined as the capacity to comprehend the nature, causes and consequences of one's and others' emotions (Cavioni, Grazzani, Ornaghi, Pepe, & Pons, 2020). It is a cognitive function that relies on social interaction and an understanding of social norms, and it allows children to label, recognize, identify, discriminate, explain, describe, predict, control the expression and regulate the experience of emotion in their everyday lives (Harris, de Rosnay, & Pons, 2016).

Components and developmental milestones of emotion understanding

A great amount of research has examined children's understanding of emotion and how this ability develops and improves throughout childhood (e.g. Sprung, Münch, Harris, Ebesutani, & Hofmann, 2015; Pons, Harris, & de Rosnay, 2004; Pons & Harris, 2000). Major gains in emotion understanding are observed from preschool age onwards. Specifically, Pons and Harris (2000) took the broad body of literature on children's acquisition of emotion understanding (see Cavioni et al., 2020, for an in-depth theoretical review) as the basis for their detailed description of nine components of emotion understanding in children aged 3 to 11 years through the Test of Emotion Comprehension (TEC). Later, Pons et al. (2004) administered the TEC to 100 typically developing (TD) children and defined three key developmental periods in the acquisition of emotion understanding, each of them in turn composed of three components. The *external* period (from the age of 5) includes the understanding of important public aspects of emotions, and children learn to identify and label different emotions based on facial expressions (Component 1). They also become aware of the fact that external contextual factors (Component 2) and reminders (Component 5) can cause or reactivate different emotions. The *mental* period (from the age of 7) includes the understanding of the mentalistic nature of emotions, so children start to understand that different people may feel different emotions in the same situation due to their different desires (Component 3) or beliefs (Component 4), and also that people can sometimes hide their actual feelings, thereby causing a discrepancy between apparent and real emotions (Component 7). Finally, the *reflective* period (from 9 years onwards) is characterized by how a person can reflect upon a given situation taking into account different perspectives, and it includes the use of cognitive strategies to regulate emotions (Component 6), the appreciation that contradictory emotions may occur simultaneously in some situations (Component 8), and also the understanding that negative emotions result from violating rules, that is, from morally unacceptable behaviour and positive feelings ensue from a morally praiseworthy action (Component 9).

Acquiring accurate emotion understanding helps children not only to manage their own feelings (which is essential for a correct construction of their identity and self-esteem), but also to manage their relationships with peers (Domitrovich, Durlak, Staley, & Weissberg, 2017; Denham, Blair, De Mulder, Levitas, Sawyer, Auerbach-Major & Queenan, 2003). Furthermore, children's emotion understanding and subsequent emotional regulation is a protective factor for both their current and their later well-being and mental health (Robson, Allen, & Howard, 2000).

Emotion understanding in individuals with DS

Down Syndrome (DS) is considered the most common genetic cause of intellectual disability (ID) and consists of a neurodevelopmental disorder that involves intellectual and adaptive functioning deficits. Children with ID have limitations in their emotional and social competence and are therefore more likely to have deficits in emotional regulation (Jacobs & Nader-Grosbois, 2020). However, individuals with DS display high sociability and more competence at establishing social relationships with others in comparison to other individuals with autism or Williams syndrome (Cebula, Moore, & Wishart, 2010). In this sense, although many researchers have studied areas of emotion understanding in individuals with DS, there are still aspects that remain underexplored (Roch, Pesciarelli, & Leo, 2020).

Following the developmental classification proposed by Pons et al. (2004), most of the studies related to emotion understanding in individuals with DS focus on the *external* period. In this regard, findings suggest both etiological and developmental differences in the emotion recognition abilities (recognition and processing of facial expressions) of children with DS in comparison to TD children (Barisnikov, Thomasson, Stutzmann, & Lejeune, 2019; Kasari, Freeman, & Hughes, 2001; Martínez-Castilla, Burt, Borgatti, & Gagliardi, 2015; Pochon & Declercq, 2014). In this regard, research has shown that individuals with DS have difficulties in recognizing negative emotions like *sadness* (Porter, Coltheart, & Langdon, 2007), *fear* (Cebula, Wishart, Willis, & Pitcairn, 2017; de Santana, de Souza, & Feitosa, 2014; Kasari et al., 2001; Porter et al., 2007; Williams, Wishart, Pitcairn, & Willis, 2005; Wishart & Pitcairn, 2000), *anger* (Kasari et al., 2001; Porter et al., 2007) or *disgust* (de Santana et al., 2014). However, Wishart, Cebula, Willis and Pitcairn (2007) highlighted the existence of particular problems regarding the recognition of *fearful* facial expressions, and argued that this difficulty was not generalized to all emotions. Moreover, problems in neutral emotions like *surprise* have also been observed (de Santana et al., 2014; Wishart & Pitcairn, 2000). In this regard, Pochon and Declercq (2014) noted that children with DS have a lack of understanding of emotional verbal labels, and therefore non-verbal experiments using dynamic stimuli should be used to better assess this ability.

Difficulties have also been found when it comes to matching an emotion with a situation (Barisnikov et al., 2019; Kasari et al., 2001), although in later development they start to be as accurate as TD when judging emotions from facial or contextual cues (Channell, Conners, & Barth, 2014).

Regarding components related to the *mental* period, Amado, Serrat and Vallès-Majoral (2016) found that children with DS obtained significantly lower scores in social cognition tasks (including emotional components related to mental state understanding and hiding emotions of TEC), in comparison to age- and language-matched TD groups. Moreover, children with DS have more difficulties in handling emotions and they use a limited repertoire of strategies for coping with frustration (Jahromi, Gulsrud, & Kasari, 2008). However, research on these components is more limited, and no evidence of complex competences has been found related to the *reflective* period.

Studies among the adult population with DS are even more limited. Regarding the components of the *external* period, adults with DS tend to show a response pattern when processing and recognizing facial expressions that is similar to that of neurotypical adults, despite obtaining poorer performance (Carvajal, Fernández-Alcaraz, Rueda, & Sarrión, 2012; Fernández-Alcaraz, Rueda, García-Andres, & Carvajal, 2010). Similar to children with DS, they still have greater difficulties with *neutral* emotions, *fear* and *surprise* (Hippolyte, Barisnikov, & Van der Linden, 2008; Hippolyte, Barisnikov, Van der Linden, & Detraux, 2009; Virji-Babul, Watt, Nathoo, & Johnson, 2012). Moreover, Carvajal et al. (2012) found that adults with DS and with moderate ID failed in configuring facial features, but not in assigning emotions. They argued that the lower part of the face provided them with more information than the upper part in emotion recognition tasks. Nevertheless, recent research did not report any special difficulties in facial expression recognition when non-verbal tasks were used (Pochon, Touchet, & Ibernon, 2017).

Recent studies have started to describe aspects related to emotional intelligence with validated questionnaires in more detail (e.g. Robles-Bello, Sánchez-Teruel, Valencia, & Delgado, 2020), but there are some competences related to emotion understanding in adults with DS that remain unexplored (e.g. those related to the *mental* and *reflective* periods).

Confusion between emotions in individuals with DS: error patterns

Simon, Rosen and Ponpipom (1996) stressed the importance of the type of confusion between facial expressions of emotion in individuals with DS, as it could be informative to understand the type of reactions that they have in some situations that involve emotional information processing. Nevertheless, these error patterns have been investigated by few authors, and almost all of them focus on facial expression recognition.

Williams et al. (2005) and Wishart et al. (2007) reported that children with DS only tended to confuse the negative facial expressions of *fear* and *sadness*. However, other studies stated that children with DS also tended to choose positive expressions instead of negative ones, that is, they selected an emotion in the opposite hedonic tone (Kasari et al., 2001; Porter et al., 2007). Hippolyte et al. (2008) also showed that adults with DS had a positive bias when judging facial expressions in comparison to a group of children with TD (e.g. they tended to maximize the items of *happiness* and minimize the items of *sadness*). Moreover, they differed from children with TD in the error pattern of the item of *sadness,* for which they usually chose the emotion of *happiness*. Similarly, Hippolyte et al. (2009) showed that in emotion recognition tasks, adults with DS rarely selected an emotion in the opposite hedonic tone (e.g. *happiness* for *anger*), except for *sadness.* Particularly, adults with DS rarely selected the *sadness* expression throughout their experiment – they tended to choose *happiness* more often than *sadness* and also *happiness* instead of the *neutral* expression.

Hence, Hippolyte et al. (2009) concluded that for an adult population with DS there is a tendency to avoid attribution of the emotion *sadness*, which is an atypical emotion processing pattern in comparison to children with TD. The authors stated that it would be important to replicate this bias through more experiments in order to confirm the specificity of these response patterns in adults with DS. Moreover, response patterns have not been explored in complex components of emotion understanding, where additional contextual cues, social norms and mental states make the correct inference of an emotion more complicated.

Predictors of emotion understanding in individuals with DS

Language is essential to acquire and develop the different emotion understanding competences (Ruffman, Slade, Rowlandson, Rumsey, & Garnham, 2003). Emotion understanding improves with age, but many individual differences in emotion understanding are explained by language skills. Pons, Lawson, Harris and De Rosnay (2003) showed that 20% of the variance of the competence of children on the TEC (from 4 to 11 years) was explained by age, but that an additional 27% was explained by language ability measured with the Test for the Reception Of Grammar (TROG; Bishop, 1989). Nevertheless, using the same measure, Albanese, De Stasio, Di Chiacchio, Fiorilli and Pons (2010) showed that the recognition of some facial expressions such as *neutral* or *surprise* was related to the linguistic level of the subjects (measured with vocabulary tasks), but non-verbal reasoning (NVR) measured with Raven's Coloured Matrices Test (Raven, 1984) was also related to emotion recognition skills in children aged between 3 and 10 years (above all on the components of the *reflexive* period). In parallel, executive functions are also associated with emotion understanding, as they enable people to remember important information about emotional events and to choose the correct emotional response (Martins, Osório, Veríssimo, & Martins, 2016). In particular, WM has a decisive impact on the development of emotion understanding in children between 5 and 11 years of age (Morra, Parella, & Camba, 2011).

Individuals with DS have poorer expressive language skills in comparison to receptive ones, so their expressive vocabulary is delayed beyond what could be expected for their mental age (Chapman, Hesketh, & Kistler, 2002). During adulthood, grammatical skills are still an area of relative weakness, whereas semantics and pragmatics are areas of relative strength (Martin, Losh, Estigarribia, Sideris, & Roberts, 2013). Furthermore, executive dysfunctions are also observed in people with DS (Costanzo, Varuzza, Menghini, Addona, Gianesini, & Vicari, 2013), and although their general executive function profile improves during adulthood, WM is an area that is especially difficult for individuals with DS during different developmental periods, including adulthood (Loveall, Conners, Tungate, Hahn, & Osso, 2017).

Regarding the predictors of emotion understanding in an adult population with DS, Hyppolyte et al. (2008) demonstrated significant associations between receptive vocabulary and inhibition measures, but not with NVR. Similarly, Pochon et al. (2017) revealed a developmental difference in this regard: NVR did not predict success in the emotion recognition tasks in the adolescents with DS group, but it did in the TD group. However, there is not much evidence regarding whether or not NVR would be important in other components related to *reflective* aspects of emotion understanding.

Considering the role of WM, Amadó et al. (2016) showed that it explained over 50% of the variability of social cognition in children with DS and younger TD children matched for language level (including *external* and *mental* components of the TEC), and 31% in age-matched children with TD. In this regard, Barisnikov et al. (2019) claimed that the difficulties of children with DS in emotion recognition tasks could result from an executive dysfunction, above all when they have to deal with complex visual information. Nevertheless, little attention has been given to this association in adult populations with DS.

Finally, concerning language skills, research has proved that emotional lexicon is considered one of the weaknesses of individuals with DS, so the low competence observed in previous emotion recognition studies is questioned (Pochon & Declercq, 2014; Pochon et al., 2017). These studies showed age-appropriate performance in recognizing emotions from facial expressions when non-verbal tasks were used. In addition, Hyppolyte et al. (2008) demonstrated an association of emotion understating with receptive vocabulary in an adult population, but the role of other important structural language skills involved in its acquisition (like receptive grammar) remains unexplored with complex emotion understanding components.

Therefore, the first aim of the present study is to correctly examine the actual emotion understanding in adults with DS in different components related to developmental periods (*external*, *mental* and *reflective*), beyond the recognition of facial expressions. In this regard, since a deficit in emotional lexicon is present in adults with DS, the non-verbal emotion understanding measure TEC is used. Additionally, a second aim is to study the presence of an atypical error pattern related to the emotional valence of emotions in the global measure. Finally, the third aim is to determine the best predictors of emotion understanding performance in this population, due to their coexisting difficulties in NVR, WM and structural language. Accordingly, it is hypothesized that:

1) Adults with DS will be comparable to a group of children with TD matched by language level in those components of emotion understanding related to the *external* developmental period, but they will show poor performance in those related to the *mental* and *reflexive* periods.
2) Adults with DS will show different patterns of errors in comparison to language-matched children with TD on the TEC, with more atypical confusion in the global measure.
3) Within the group of adults with DS, NVR, structural language and WM will make a different contribution depending on the components of TEC (*external*, *mental* or *reflexive*).

2. Materials and methods

2.1 Participants

Adults with DS. All the participants in the DS sample were recruited by contacting the Down Syndrome Foundation of Castellón (Spain). The criteria for inclusion in the sample were the following:

1) Having a diagnosed mild to moderate ID (IQ lower than 70 defined by the standardized assessments conducted at each centre);
2) Being aged between 18 and 45 years old (due to the likelihood of Alzheimer's disease in this population when they reach late adulthood, like 45 years and older) (Esbensen, Boshkoff, Amaral, Tan, & Macks, 2015).

Twenty-two participants with DS (9 men, 13 women) aged between 18 and 41 years were recruited (M = 329.91 months; SD = 70.46 months; Range = 227–492). Eight of them had a mild intellectual disability (4 men, 4 women), and fourteen had a moderate intellectual disability (5 men, 9 women).

Children with TD. A control group consisting of 18 boys and 4 girls was recruited from a public school in Castellón, matched by language level to each person with DS by means of a receptive vocabulary test, the Peabody test (PPVT-III, Dunn, Dunn, & Arribas, 2006), following the example of similar studies in adult populations with DS (e.g. Hippolyte et al., 2008). Children ranged from 5 to 12 years old (M = 92.82 months; SD = 21.31 months; Range = 71–148). No significant differences were found at the receptive vocabulary level between the group of adults with DS (M = 86.18; SD = 30.10; Range = 44–142) and the group with TD (M = 88.36; SD = 27.66; Range = 38–136).
The criterion used to select each child for the TD group was having a test level similar to that of an adult with DS (based on the raw scores obtained on the PPVT-III). In this regard, of all the children with TD assessed with PPVT-III in the public school where we had been given consent to conduct our study, there were not enough boys and girls to have the same number of males and females as in the group with DS. Although this is a limitation, previous studies using the TEC identified no gender differences (e.g. Albanese & Molina, 2008; Pons et al., 2004).

2.2 Tasks

Non-verbal reasoning (NVR)

The Coloured Progressive Matrices test (Raven, Court, & Raven, 1996) was used to assess NVR and learning potential. This scale is appropriate for both school-age children and adults with ID, as is the case in the present study. It contains 36 items, and its direct score can therefore range between 0 and 36 points. The standardization study generated a value of .80 in test-retest reliability.

Structural Linguistic Skills

a) Receptive grammar measure.

The Spanish version of TROG (Bishop, 1989), called *Comprensión de Estructuras Gramaticales* (CEG, Mendoza, Carballo, Muñoz, & Fresneda, 2005) was used to measure the understanding of grammatical structures in children between 4 and 11 years old. It contains 80 items, so the direct score ranges between 0 and 80 points. The CEG test has adequate psychometric properties: Reliability (.91); Validity, correlations values: CEG-PPTV (r = .809, p < .001) and CEG–ITPA (r = .644, p < .001) (PPVT, Peabody, Dunn et al., 2006; ITPA, Kirk, McCarthy, & Kirk, 1968). Furthermore, more than half of the elements provided a discrimination index greater than 0.3 among subjects with higher scores and lower scores in the test (Muñoz, Fresneda, Mendoza, & Carballo, 2008).

b) Receptive vocabulary measure.

The Spanish version of the PPVT-III for children between 2 and 17 years old (Dunn et al., 2006) was used to assess the level of comprehensive vocabulary of the sample. The test items are organized in blocks of 12 items, each ordered by age. The total score can range between 0 and 192 points. This test has adequate psychometric properties: a) Internal consistency of items: High reliabilities (minimum of .90) were reported for the 25 age groups of the norm sample with a median reliability of .95; b) Split half reliability: reliabilities ranged from .86 to .97 for the standardization age groups for both forms; and c) Test-retest: corrected coefficients were reported between .91 to .94 with no difference in magnitude between the two forms (Hayward, Stewart, Phillips, Norris, & Lovell, 2008).

c) Structural language composite variable.

A composite structural language score was created for the predictive study related to hypothesis 3, to examine structural language as a complex construct. The two receptive language measures were included (CEG and PPVT-III) because both linguistic skills had been associated with emotion understanding in previous studies with participants with DS and with TD (e.g. Hyppolyte et al., 2008, for receptive vocabulary; or Pons et al., 2003, for receptive grammar). First, we confirmed that the two measures were highly correlated within the sample (n = 44, r = .620, p < .001). However, as CEG and PPVT-III have different scoring ranges, a composite score was created by weighting them equally. Specifically, the language composite variable was obtained by adding together the two weighted raw scores. The final score ranged from 0 to 100 with each language measure representing ½ of the structural language composite variable.

Working Memory (WM)

The working memory subtest “Digit Span” from the WISC-IV (Wechsler, 2005) was used to assess WM. According to Gordon and Olson (1998), the test of memorizing numbers in direct and reverse order plays a key role in the evaluation of this capacity. This test consists in repeating numbers both in direct order (8 items with 2 attempts each) and in reverse order (as before), a maximum score of 36 points being possible. Psychometric properties are the following: a) Internal consistency: the reliability coefficient for Digit Span Forward is .83, and for Digit Span Backward it is .80; b) Test-retest stability: corrected coefficients were reported between .81 and .83 for Digit Span with no significant differences between the two forms; c) Exploratory and confirmatory factor analyses confirmed that the Digit Span subtest correlated significantly with the Working Memory Factor (.67); and d) Validity: the corrected correlation between the Digit Span in the WISC–III and WISC–IV was .79.

Emotion understanding test: The Test of Emotion Comprehension (TEC)

The Test of Emotion Comprehension (TEC; Pons & Harris, 2000) was used to assess the emotion understanding of the sample of participants. The Spanish version of the test is currently in the validation phase, so to conduct the present study one of the authors of the TEC provided the research group with the Spanish version of the instructions adapted by professors Carlos Hernández Blasi and Francisco Pons.

The TEC is aimed at children between 3 and 11 years old and it has been extensively used to assess whether children’s emotion understanding is age-appropriate. It has also been used to compare cultures, and among children with atypical development including children with hearing loss or autism (see review in Cavioni et al., 2020). The instrument allows for the assessment of nine components of emotion understanding (Table 1). As pointed out by Pons et al. (2004), components 1, 2 and 5 are usually successfully completed at the age of around *5 years* (*external* period); components 3, 4, 7, at around *7 years* of age (*mental* period); and components 6, 8 and 9 between *9 and 11 years* of age (*reflective* period).

Table 1 here

The TEC consists of a picture book composed of twenty-three cartoon scenario stories (black and white drawings) and it is available in both girl and boy versions. In the first component (5 items), the child is asked to identify the correct facial expression corresponding to the target emotion, selecting (pointing at) one option from among four possible choices. The five possible emotions to appear are *happy*, *sad*, *angry*, *scared* and/or *well*. The remaining components are formed by items that include a drawing in which the main character's face is omitted (top of the cartoon), and after hearing a brief story (read by the examiner), the participant is asked to choose (point to) the correct emotion for the main character from among four choices (bottom of the cartoon). Again, the possible emotions to choose from are *happy*, *sad*, *angry*, *scared* and/or *well*.

In order to address hypotheses 1 and 3, the original scoring was followed, and children received 1 point for passing a component (see Table 1). So, the *global TEC* score ranged from 0–9 and it is obtained by adding the sub-scores for the nine components. Likewise, *Group 1 – External* ranged from 0–3, *Group 2 – Mental* ranged from 0–3, and *Group 3 – Reflective* ranged from 0–3.

In order to address hypothesis 2 and to investigate error patterns beyond facial expression recognition in adults with DS, all the responses given to all the items on the TEC were coded (that is, coding each response that the participant had pointed to from the four possible options, regardless of whether it was correct or incorrect).

As remarked by Fidalgo, Tenenbaum and Aznar (2018), the TEC has good test-retest reliability after a 3-month delay (r (18) = .84), and a good test-retest correlation after a 13-month delay (r (40) = .64 and r (32) = .54) (Pons, Harris, & Doudin, 2002; Pons & Harris, 2005). Moreover, internal consistency used as a measure of reliability (Cronbach's alpha) showed all the values were in the range of .61 to .97 (e.g. $\alpha = .79$, in the Italian version used by Albanese & Molina, 2008).

Note on the scores used from the assessments:

In the data analysis, the direct scoring of all the tests (raw score) was used instead of the percentiles (standard score) because the clinical sample is made up of adults, in line with the example of previous studies (Hippolyte et al., 2008).

2.3 Procedure

First of all, the Down Syndrome Foundation of Castellón (Spain) was contacted, and an information sheet with the method and objectives of the research was given to those responsible for running the institution. The professionals (psychologists and educators) who work there explained the project to the adult participants with DS and their families. Professionals from the institution helped the research group to identify adults with DS aged 18–45 years with mild or moderate intellectual disabilities. After that, all permissions and informed consents were obtained from the organization, students and parents or authorised representatives of the participants prior to the administration of the measures.

Subsequently, the first author administered the tests to the sample with DS. In the first session (60 minutes), non-verbal reasoning and linguistic and working memory measures were administered. The order of presentation within the session was counterbalanced to prevent order effects. The TEC (30 minutes) was administered in one subsequent session.

Afterwards, the score on the PPTV-III was used to select the control group of language-matched TD children. Accordingly, a public school in the same city was contacted to recruit a group of children with a linguistic age similar to that of the adults with DS. Again, school and parents/guardians also gave their informed consent. Children were tested individually during school-time following the same procedure as the DS group.

All measures were administered in accordance with their manuals and always individually in classrooms or offices that were made available for this purpose at the institution itself (in the case of the DS group) or at the school (in the case of the control group).

2.4 Data analysis

The data were analysed using the IBM SPSS Statistics 26.0 – 2019 program. First, the Shapiro-Wilk test was performed to find the normality of the study sample in the dependent variables. It was found that for the dependent variables related to TEC, the data did not have a normal distribution ($p < .05$).

With respect to hypothesis 1, the non-parametric Mann-Whitney U test was used to perform group contrasts in the emotional and related measures. The statistical formula described by Tomczak and Tomczak (2014) was used to obtain the effect size of the sample for non-parametric samples ($r = Z / \sqrt{N}$, where Z is taken as an absolute value).

In relation to hypothesis 2, an absolute frequency test was run on each item of the TEC, in order to analyse existing error types.

Finally, with respect to hypothesis 3, non-parametric correlations (Spearman-Rho) and linear hierarchical regressions were performed within the DS and the TD groups. The hierarchical linear regression analysis was conducted for each sample separately (n = 22), and a bootstrapping method was implemented using 1000 bootstrap samples to derive robust estimates of standard errors, confidence intervals and p values of the regression model.

3. Results

3.1 Intergroup comparisons in emotion understanding and related variables

Table 2 shows the descriptive data of the sample in relation to the variables age, gender, NVR, structural linguistic skills (grammar and vocabulary) and WM. The group with DS obtained a low average in all of them except for age, and significant differences were observed in age ($U = .000$, $p < .001$, $r = .856$), NVR ($U = 141.00$, $p = .017$, $r = .358$), grammar ($U = 54.50$, $p < .001$, $r = .664$) and WM ($U = 87.00$, $p < .001$, $r = .551$). In addition, a large effect size was appreciated in all comparisons except for grammar, where it was medium.

Table 2 here

Table 3 shows the descriptive data of the TEC and its different components. For the analysis, the components were grouped by developmental period proposed by Pons et al. (2004): Group 1 (External: facial recognition of emotions, external causes and emotions based on memories), Group 2 (Mental: emotions based on desires, emotions based on beliefs and hiding emotions) and Group 3 (Reflective: regulation of emotions, mixed emotions and morality).

In general, low means of the group with DS were observed in all the components, taking into account that they are usually successfully accomplished around the age of 11 years. In addition, there were significant differences in favour of the group of children with TD in the task as a whole, that is, in the sum of the components ($U = 137.00$, $p = .012$, $r = .381$), with a medium effect size.

When analysing the components by groups, significant differences were observed in Group 1 (External) with a large effect size (U = 124.50, p = .001, r = .518), and a tendency towards significance in Group 2 (Mental), with a medium effect size (U = 168.50, p = .058, r = .286). In Group 3 (Reflective), although it is the one in which the group with DS presented the poorest results, there were no significant differences with respect to the control group.

Table 3 here

3.2 Error type analysis in the emotion understanding measure (TEC)

Table 4 shows the error type analysis of the responses to the items in the TEC task among the adults with DS and children with TD, respectively.

Regarding Component 1 (facial expressions), the most predominant error within the DS group was confusion between *well* and *happy*, followed by mistaking the *sad* face for *anger* (an error not present in the TD group). Additionally, a single participant with DS confused facial expressions of different valences (*happy–scared*).

In Component 2 (external causes), in a situation of *waiting for the bus* (where the answer *well* was expected), some participants with DS selected *happy*, whereas fewer children with TD committed that mistake. Moreover, in contrast to children with TD, some participants with DS confused certain negative emotions (*anger*, *sadness* and *scared*).

No confusion was observed in component 3 (emotions based on desires), since the majority of the group with DS answered correctly.

Regarding Component 4 (emotions based on beliefs, *a rabbit that eats a carrot without seeing that there is a wolf behind him*, and is therefore *happy*), some participants with DS answered *scared*, but others responded with *anger* (an error not common in the TD group).

In the case of Component 5 (emotions based on memories, *the child sees the picture of his rabbit that died a while ago*, the expected response being *sad*), participants with DS failed to choose *happy*, but also some failed to choose *scared*.

Regarding Component 6 (emotional regulation strategies, where they were asked what they would do *to stop being sad* and the correct answer is *to think about something else*), similar errors were observed in the group with DS and in the TD group.

In Component 7 (hiding emotions, where the main character pretends to be *happy*, but his real emotion is *angry* at *not having as many marbles as his friend*), in the group with DS *anger* was again confused with *scared*, which was uncommon in the TD group (here, the typical error was confusing *angry* with *well* or *happy*, the feigned emotion).

Regarding Component 8 (mixed emotions, where a child is going to ride a bicycle for the first time, and is simultaneously *happy* and *scared*), participants with DS made similar mistakes to the TD group (e.g. just *happy*).

Finally, in Component 9 (morality, a child *does not tell his mother the truth* about something he should not have done, which should cause *sadness* in him), the predominant error for the DS group was *anger*, whereas for the TD group it was *well*.

Table 4 here

3.3 Correlational analysis between TEC and related variables

In order to determine the relationship between emotion understanding measured with the TEC and the participants' levels of structural language, WM and NVR, a non-parametric correlational study was carried out (see Table 5).

Significant strong/moderate and positive correlations were observed within the adults with DS group between the TEC and the rest of the variables (NVR, $p = .024$; Gram, $p < .001$; Vocab, $p < .001$; WM, $p = .001$). Nevertheless, when components of TEC are analysed separately, Group 1 – External was only positively and significantly correlated in a strong way with grammar ($p = .021$) and WM ($p = .010$). Group 2 – Mental was positively and significantly correlated in a strong way with grammar ($p = .005$) and vocabulary ($p = .003$). Finally, Group 3 – Reflective was positively, moderately and significantly correlated with NVR ($p = .040$) and grammar ($p = .022$), and strongly correlated with vocabulary ($p = .005$) and WM ($p = .017$).

Regarding the group of children with TD, significant, moderate and positive correlations were observed between the TEC and the linguistic variables (Gram, $p = .043$; Vocab, $p = .046$). However, when analysed by groups, Group 1 – External and Group 2 – Mental were not correlated with any of the variables. Lastly, Group 3 – Reflective correlated positively and strongly with age ($p = .010$) and vocabulary ($p = .013$), and moderately with NVR ($p = .037$).

Table 5 here

3.4 Predictive analysis of the variables on TEC

Subsequently, we went on to determine the predictive capacity of the variables on the scores obtained on the TEC by means of a hierarchical linear regression. This analysis was performed both on the total components of the TEC and on each group of components according to the age of acquisition. To this end, three variables were used: NVR, WM and the language composite variable.

Table 6 shows the regression analysis of the general model performed for both groups. Regarding the group of adults with DS, 60% of the variance was explained: F (3, 18) = 9.037, R^2 = .601, *p* = .001, NVR being significant in step 1 (β = .502) and WM being significant in step 2 (β = .584). In contrast, in the group of children with TD, 40% of the variance was explained: F (3, 18) = 3.957, R^2 = .397, *p* = .025, NVR being significant in step 1 (β = .379) and language being significant in step 3 (β = .695).

Table 6 here

In Table 7 the same regression was carried out on the components of Group 1 (External). For the group of adults with DS, the model represents 33% of the variance: F (3, 18) = 2.948, R^2 = .329, *p* = .061. The significance of WM stands out in step 2 (β = .540) and step 3 (β = .637). For the group of children with TD, the model also accounted for 33% of the variance: F (3, 18) = 2.993, R^2 = .333, *p* = .058. However, none of the predictors were significant in any of the steps, although a tendency towards significance was observed for language in Step 3 (β = .690).

Table 7 here

Table 8 represents a model that takes the components of Group 2 (Mental) as the dependent variable. For the adults with DS, this model explains 43% of the variance: F (3, 18) = 4.595, R^2 = .434, *p* = .015, and the significance of the language variable stands out in step 3 (β = 1.006). For the children with TD, this model explains only 7% of the variance: F (3, 18) = .443, R^2 = .069, p = .725. Again, none of the predictors were significant in any of the steps.

Table 8 here

Finally, the model represented in Table 9 has the components of Group 3 (Reflective) as the dependent variable. For the adults with DS, this model explained 36% of the variance: F (3, 18) = 3.444, R^2 = .365, p = .039, the significance of NVR standing out in step 1 (β = .468), and a tendency towards significance was observed for WM in step 2 (β = .402). For the children with TD, this model explained 31% of the variance: F (3, 18) = 2.675, R^2 = .308, p = .078, the significance of NVR standing out in step 1 (β = .510), step 2 (β = .516) and step 3 (β = .417).

Table 9 here

4. Discussion

The purpose of the present study was to conduct an in-depth examination of the real emotion understanding in adults with DS, beyond emotional facial expression recognition. A first specific aim was to examine their competence on the *external*, *mental* and *reflective* components of emotion understanding. A second aim was to study whether the error pattern was typical or atypical. Finally, the third specific aim was to find the best predictors of emotion understanding skills on the different aspects assessed, due to coexisting difficulties in NVR, WM and structural language in adults with DS.

Firstly, it was hypothesized that adults with DS would be as competent as a group of language-matched children with TD in *external* components of emotion understanding, but they would exhibit a poor performance in those related to *mental* and *reflexive* ones. In this regard, between-group comparisons showed that, despite being skills that should be acquired between 5 and 11 years of age, adults with DS obtained lower scores than language-matched children with TD in the overall measure. Specifically, significant differences were observed in the *external* components of the TEC (recognition of emotions, emotions based on memories, and external causes) – components that should have been acquired around the age of 5. Moreover, a difference closer to significance was also observed on *mental* components (emotions based on desires, beliefs based on beliefs, and hiding emotions), which are typically acquired around the age of 7. Nevertheless, even though adults with DS presented greater difficulty in *reflective* components (mixed emotions, regulation and moral emotions), no differences were observed in children with TD, possibly because many participants within the TD group are still too young (the average age of the TD group was 7;6 years, and these components are acquired from 9 years on).

These results confirm that adults with DS did manifest difficulties in *external* components of emotion recognition (Carvajal et al., 2012; Fernández-Alcaraz et al., 2010). Specifically, in the facial expression component, some participants failed to correctly recognize the five emotions assessed, with more problems with the neutral emotion *well* as found previously (Hippolyte, Barisnikov, & Van der Linden, 2008; Hippolyte, Barisnikov, Van der Linden, & Detraux, 2009; Virji-Babul, Watt, Nathoo, & Johnson, 2012). Moreover, difficulties have also been found when matching an emotion with a situation, in accordance with previous research (Barisnikov et al., 2019; Kasari et al., 2001), but also with a reminder, an aspect that was not explored. Similarly, additional problems related to the *mental* and *reflective* components of emotion understanding have been found, but these problems are in keeping with their receptive vocabulary language skills. The data from the present study therefore confirm that some problems in *external* and *mental* components observed in children with DS (Amadó et al., 2016) continue into adulthood, and also add information about the *reflective* components that remained unexplored in the adult population (Roch, Pesciarelli, & Leo, 2020). Moreover, it seems that the age-inappropriate competence demonstrated by adults with DS in *external* components is not only linked to their emotional lexicon problem (as questioned by Pochon & Declercq, 2014, or Pochon et al., 2017) or their receptive vocabulary level (Hyppolyte et al., 2008), but also to other receptive language skills (like grammar), NVR and WM, where adults with DS performed worse than children with TD in the present study.

The second hypothesis stated that adults with DS would show different patterns of errors in comparison to language-matched children with TD. In this sense, more atypical confusion between emotions was expected in the global measure. The error type analysis showed that, in addition to more errors than the group of children with TD, the group of adults with DS also made different kinds of errors, which also varied depending on the type of emotional component analysed.

Regarding the *external* components, the neutral emotion *well* was confounded with *happy* in Components 1 (recognition of emotions) and 2 (external causes), a confusion present in children with TD but to a lesser extent. However, confusion between emotions with a negative valence was also observed (*sadness, fear* and *anger*) across the three components, which was not an error present within the TD sample. Furthermore, in component 5 (emotions based on memories), they confused emotions with different valences (*happiness* and *sadness*). So, the confusion between *well* and *happy* and the negative emotions (*sadness, fear* and *anger*) for component 1 (facial expression) could be explained by the problems they have with emotional lexicon when it comes to retrieving the lexical label that corresponds to each emotion (Pochon & Declercq, 2014; Pochon et al., 2017). However, as the TEC is a measure that does not require an oral response for component 2 (external causes), the positive bias found in previous research is confirmed (Hippolyte et al., 2008), but also the possibility that waiting for a bus might represent a positive reminder for these adults (e.g. a reminder linked with their autonomy). Regarding findings in component 5, any confusion might be due to a problem in the relevance of the type of memory selected (e.g. *happy* as a result of the memory of the good times spent with their pet), to a problem of WM that makes it difficult for them to remember the sad part of the story (*that the rabbit had died*) or even because of the misinterpretation or partial understanding of the story (*scared* of death).

Regarding the *mental* components, although there seem to be no special difficulties in the association of emotions with desires, problems do arise in the association of emotions with beliefs (component 4) and hiding emotions (component 7). In this regard, although some errors are common in children with TD (e.g. selecting *scared* with *happy* in component 4, as a result of not inferring the false belief of the rabbit; or selecting *happy* instead of *angry* in component 7, as a result of not being aware of the fact that the character wants to hide his real emotion), atypical errors were also found (e.g. selecting *angry* in component 4, or *scared* in component 7). In this regard, it seems that some participants with DS are making similar mistakes to some children with TD, possibly because their theory of mind skills fail to remain in keeping with their language level (Ruffman et al., 2003). However, there are other participants with DS that select atypical options for those stories, and this happens when those emotions are within the negative valence. It seems that, when the situations are unfamiliar or hypothetical, they tend to confuse them in a more atypical way, in accordance with previous finings (Williams et al., 2005; Wishart et al., 2007).

Finally, regarding the *reflective* components, errors found in component 7 (regulation) and 8 (mixed emotions) were similar to those found within children with TD. Nevertheless, in Component 9 (moral emotions), participants with DS committed different errors to the TD group (e.g. whereas children with TD selected *happy* instead of *sad* showing they still do not understand the morality involved in lying to their mother, adults with DS failed to select that the child would feel *angry*). So, again, they misunderstand the situation and focus on incorrect, partial or biased aspects of the situation (e.g. maybe they select *angry*, because the mother would be angry if she discovers the lie), or because the situation is so hypothetical for them that it is very difficult to select the correct negative emotion.

The error type analysis therefore suggests that it is important to work on how they interpret and process emotions in contextualized situations because our results reveal the existence of certain atypical error patterns and biases in the understanding of basic emotions that continue into adulthood. These errors could explain some of the socio-emotional difficulties observed in social interaction in their day-to-day undertakings, as underlined by Simon et al. (1996): for example, typical errors found in *mental* aspects could explain immature behaviours due to the difficulty in anticipating others' needs (e.g. offering to do favours), the excessive sincerity or affection they could show towards other people (even with strangers) or a childish attitude displayed when attempting to overcome problematic situations or when faced with a high emotional load (e.g. exaggerated sadness in order to get attention). However, atypical confusion between negative emotions could explain some atypical behaviours present in DS: e.g. they cry as a response to *anger* (e.g. in an argument) or they *shout* or get blocked in response to *sadness* (e.g. when they have done an exercise wrong).

Finally, the third hypothesis stated that for adults with DS, their level of NVR, structural language and WM will make a different contribution depending on the components of TEC (*external*, *mental* or *reflexive*). The correlational analyses showed that all the variables were related to the overall measure with a different association depending on the different components. However, even though the age of the participants ranged from 18 to 41 years old, age did not correlate with competence in the task, probably because it is an adult population whose members have completed their emotional development. For children with TD, structural language was the only aspect related to global competence in the TEC, and age and NVR only correlated with *reflective* components.

The hierarchical linear regressions conducted with (overall) emotion understanding and with the grouped components (*external*, *mental* or *reflexive*) have confirmed the existence of variability in relation to the predictive variables in both groups. Within the DS group, WM and NVR were the best predictors of global competence in TEC. However, when the analysis was performed differentiating the components, WM best predicted *external* ones, while structural language best predicted *mental* ones, and NVR best predicted *reflective* ones. In contrast, among the children with TD, structural language and NVR skills were the best predictors of the global competence in TEC. Nevertheless, when the analysis was performed differentiating the components, none of the variables predicted *external* and *mental* components significantly, but NVR did predict *reflective* components.

In this regard, results in the TEC measure are interesting when taken separately according to the developmental classification by Pons et al. (2004). It seems that for adults with DS, WM is essential for *external* components (e.g. memory for facial expressions, for situations already experienced or for important details of the narration), where the items do not need an important degree of linguistic processing and the situations are more common so they do not need to pay attention to so many visual and verbal cues to reach a creative solution. These results are in line with previous findings in children with DS (Amadó et al., 2016 Barisnikov et al., 2019), and also in children with TD (Morra et al., 2011; Pons et al., 2002). However, structural language level is essential for the understanding of *mental* components (e.g. to understand the stories that enable attribution of the correct mental states to the main character, that is his desires, beliefs or intentions). The importance of structural language on emotion understanding had been demonstrated for children with TD with grammar measures (Pons et al., 2003), but this contribution remained unexplored in adults with DS. Hence, our results indicate that in addition to the problems with the emotional lexicon (Pochon & Declercq, 2014; Pochon et al., 2017), there are also other important linguistic aspects involved in mentalistic aspects of emotion understanding in adults with DS. Finally, NVR seems crucial for the understanding of *reflective* components (morality, regulation of emotions, and mixed emotions), thereby indicating that the most complex aspects of emotion understanding require, above all, a creative search for solutions in terms of representational ability to find the right visual or verbal cue, as has also been observed for children with TD in this study and in previous research (Albanese et al., 2010).

Since the study compares a population of adults with a sample of children, it should be remarked that the contribution of the cognitive and linguistic skills to emotion understanding is slightly different in the two samples. Although the contribution of NVR is very similar in both groups, it seems that for children with TD structural language is an additional predictor of the variance observed, whereas WM has the same effect for adults with DS. In this sense, structural language seems to be crucial during the period of acquisition and development (Ruffman et al., 2003). Yet, WM is needed to manage emotional knowledge once emotional development is completed, as it enables people to remember important information about emotional events, and also to select the correct emotional responses (Martins et al., 2016), above all when that emotional knowledge has already been acquired.

A strength of the present study is that all the tests used to assess the sample (NVR and structural linguistic skills) are receptive measures because the TEC also requires a receptive response, and therefore we aimed to reduce expressive language loads. However, a limitation is that the classic WM test Digit Span was used, and it is not a visual instrument. Nevertheless, we used this test because it plays a key role in the evaluation of short-term and verbal WM when language is involved in a situation (e.g. to remember key information in an emotional story presented in the TEC) and the visual information is always present.

Additional limitations of this study include the sample size of the two groups, as some of the predictors of emotion understanding do not reach significance and larger samples would have shown the association between them better. Moreover, the TD group was made up of a different number of males and females than the group of adults with DS, and therefore gender has not been considered a predictive variable in the present study. Finally, the limited number of elements in some components of the TEC (e.g. there is only one item to assess components 4 to 9) must be noted, which prevents them from being assessed in a more complete manner and with a variety of situations. In addition, future studies could expand the number of linguistic (e.g. semantic and pragmatic aspects) and executive function variables (e.g. control inhibition skills, as pointed out by Li, Liu, Yan and Feng, 2020), in order to obtain greater variability in the results and even to be able to explain the rest of the variance.

5. Conclusion

Adults with DS have problems in different components of their emotion understanding, with levels below those of language-matched children with TD. The pattern of their errors shows atypical confusion between negative emotions (e.g. *anger*, *scared*, *sadness*). In general, the emotion understanding difficulties of adults with DS are related to their NVR, WM and structural language level, but a different contribution is observed depending on the aspects assessed (*external* associated with WM, *mental* associated with structural language skills, or *reflective*, associated with NVR).

Emotion understanding is a protective factor for current and later well-being and mental health (Robson et al., 2000). These problems could explain the poorly adaptive behaviours observed when it comes to relating with other people (Domitrovich et al., 2017; Denham et al., 2003). In this sense, our findings emphasize the possibility of using WM training to improve *external* components of emotion understanding in this population, structural language to improve *mental* aspects and NVR to improve *reflective* ones. In this regard, a recent study found that WM could explain the training effects of executive functions on emotion understanding, which provides further evidence of the mental mechanism (Li et al., 2020). Furthermore, such interventions focus on those situations that involve negative emotions and atypical confusion.

Acknowledgements

We wish to thank all the adult and child participants who took part in the present study, above all the Down Syndrome Association and Foundation of Castellón (Spain). We are also grateful for the grant from the Universitat Jaume I of Castelló (UJI-A2016-12).

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Table 1. *Description of the Test of Emotion Comprehension (TEC).*

Component	Name	Age of acquisition	Period	Scoring
1	Recognition of emotions	5 years	External	1 point if participants were correct on at least four out of five items
2	External causes	5 years	External	1 point if participants were correct on at least four out of five items
3	Emotions based on desires	7 years	Mental	1 point if participants were correct on the four questions
4	Emotions based on beliefs	7 years	Mental	1 point if participants chose the correct answer from the four options given
5	Emotions based on memories	5 years	External	1 point if participants chose the correct answer from the four options given
6	Regulation of emotions	9–11 years	Reflective	1 point if participants chose the correct answer from the four options given
7	Hiding emotions	7 years	Mental	1 point if participants chose the correct answer from the four options given
8	Mixed emotions	9–11 years	Reflective	1 point if participants chose the correct answer from the four options given
9	Moral Emotions	9–11 years	Reflective	1 point if participants were correct on both questions

Table 2. *Descriptive data and intergroup comparisons between groups of adults with DS and children with TD on age and related measures.*

	DS (n=22)			***TD (n=22)***				
	M	***SD***	***Range***	***M***	***SD***	***Range***	***U***	***p***
Age (months)	329.90	70.46	227-492	92.81	21.31	71-148	.000	<.001
Gender	9/13	-	-	18/4	-	-	-	-
NVR (0 - 36)	17.59	6.83	4 - 31	23.64	9.74	0-46	141.00	.017
Gram (0 - 80)	45.00	10.27	30-73	61.50	9.56	32-76	54.50	<.001
Vocab (0 - 192)	86.18	30.10	44-142	88.36	27.66	38-136	223.00	.655
WM (0 - 16)	8.59	3.22	4 - 14	13.00	2.96	9-19	87.00	<.001

Note: Age = months; NVR = non-verbal reasoning; Gram = grammar; Vocab = vocabulary; WM = working memory.

Table 3. *Descriptive data and intergroup comparisons between groups of adults with DS and children with TD on the TEC.*

		DS (n=22)			***TD (n=22)***				
	Age of acquisition	***M***	***SD***	***Range***	***M***	***SD***	***Range***	***U***	***p***
TEC components (0 - 9)	4–11 years old	5.86	1.86	3-9	7.27	1.16	4-9	137.00	.012
Group 1 - External (0 - 3)	5 years old	2.23	.81	1-3	2.91	.43	1-3	124.50	.001
Group 2 - Mental (0 - 3)	7 years old	2.14	.77	1-3	2.54	.74	1-3	168.50	.058
Group 3 - Reflective (0 - 3)	9 years old	1.54	1.10	1-3	1.91	.75	1-3	193.00	.229

Note: Group 1: Components 1, 2, 5; Group 2: Components 3, 4, 7; Group 3: Components 6, 8, 9.

Table 4. *Error type analysis of the responses in each item of the TEC.*

	DS (n=22)					***TD (n=22)***				
Item[1] (C[2]) (expected emotion[3])	***H[4]***	***S[4]***	***A[4]***	***W[4]***	***Sc[4]***	***H[4]***	***S[4]***	***A[4]***	***W[4]***	***Sc[4]***
Item 1, C1 (Sad)	0	**18**	4	0	–	0	**22**	0	0	–
Item 2, C1 (Happy)	**21**	0	–	0	1	**21**	0	–	1	0
Item 3, C1 (Angry)	1	–	**21**	0	0	0	–	**22**	0	0
Item 4, C1 (Well)	10	0	0	**12**	–	2	0	0	**20**	–
Item 5, C1 (Scared)	0	–	1	1	**20**	0	–	1	0	**21**
Item 6, C2 (Sad)	0	**19**	3	0	–	0	**22**	0	0	–
Item 7, C2 (Happy)	**22**	0	–	0	0	**22**	0	–	0	0
Item 8, C2 (Angry)	0	–	**18**	2	2	1	–	**21**	0	0
Item 9, C2 (Well)	11	1	1	**9**	–	3	2	2	**15**	–
Item 10, C2 (Scared)	0	–	2	0	**20**	0	–	0	0	**22**
Item 12 A, C3 (Sad)	0	**22**	–	0	0	1	**17**	–	3	1
Item 12 B, C3 (Happy)	**20**	0	–	2	0	**20**	1	–	0	1
Item 13, C4 (Happy)	**9**	–	4	1	8	**19**	–	0	2	1
Item 17, C5 (Sad)	6	**13**	–	1	2	0	**22**	–	0	0
Item 19, C7 (Angry)	1	–	**17**	0	4	1	–	**19**	1	1
Item 22, C9 (Sad)	1	**11**	10	0	–	1	**15**	1	5	–
	cover	***do***	***think***	***nothing***		***cover***	***do***	***think***	***nothing***	
Item 18, C6 (To think)	0	5	**12**	5		4	3	**12**	3	
	H	***S/Sc***	***H/Sc***	***Sc***		***H***	***S/Sc***	***H/Sc***	***Sc***	
Item 20, C8 (Happy/Scared)	3	4	**12**	3		3	4	**13**	2	

Note[1]: Items from 14 to 16 are not included in this table as they are information items (related to the narration of the story). Likewise, items 11 and 21 are not included because they are control items.

Note[2]: C = Component; C1 = recognition of emotions; C2 = external causes; C3 = emotions based on desires; C4 = emotions based on beliefs; C5 = emotions based on memories; C6 = regulation of emotions; C7 = hiding emotions; C8 = mixed emotions; C9 = moral emotions.

Note[3]: H = Happy; S = Sad; A = Angry; W = Well; Sc = Scared

Note[4]: Bold figures represent the correct answer for each item, and the symbol – means that this emotion was not present among the four options given.

Table 5. *Correlations between emotion understanding and age, non-verbal reasoning, language and executive functions in the group with DS (n = 22) and TD (n = 22).*

DS group (n = 22)					
	Age	***NVR***	***Gram***	***Vocab***	***WM***
Total components TEC	-.118	.480*	.725**	.754**	.680**
Components Group 1 - External	-.247	.193	.488*	.389	.535*
Components Group 2- Mental	-.145	.309	.581**	.611**	.384
Components Group 3 - Reflective	.000	.441*	.485*	.572**	.502*
TD group (n = 22)					
	Age	***NVR***	***Gram***	***Vocab***	***WM***
Total components TEC	.416	.401	.435*	.429*	.119
Components Group 1 - External	.224	.294	.362	.362	.346
Components Group 2- Mental	-.009	-.007	.104	-.039	-.016
Components Group 3 - Reflective	.528**	.448*	.337	.522*	.114

Note[1]: *p <.05; **p <.01

Note[2]: Age = months; NVR = non-verbal reasoning; Gram = grammar; Vocab = vocabulary; WM = working memory.

Note[3]: Group 1 – External (5 years old): Components 1, 2, 5; Group 2 – Mental (7 years old): Components 3, 4, 7; Group 3 – Reflective (9 years old): Components 6, 8, 9.

Table 6. *Summary of the regression coefficients for TEC scores within the DS group and the TD group (bootstrap results based on 1000 bootstrap samples).*

			DS (n=22)			
Predictor	ΔR^2	***B***	**SE B**	***β***	***t***	***p***
Step 1	.252					
Constant		3.461	.875		3.493	.002
NVR		.137	.049	.502	2.594	.006
Step 2	.290					
Constant		1.648	.043		1.730	.093
NVR		.075	.043	.275	1.629	.093
WM		.338	.085	.584	3.464	.002
Step 3	.060					
Constant		.697	.063		.645	.647
NVR		.025	.063	.090	.457	.647
WM		.161	.108	.278	1.128	.152
Language		.066	.050	.481	1.640	.210

			TD (n=22)			
Predictor	ΔR^2	***B***	**SE B**	***β***	***t***	***p***
Step 1	.144					
Constant		6.203	.672		9.864	.001
NVR		.045	.024	.379	1.833	.050
Step 2	.017					
Constant		5.615	1.421		4.935	.003
NVR		.041	.027	.340	1.547	.077
WM		.054	.102	.137	.625	.543
Step 3	.236					
Constant		4.254	1.382		3.815	.007
NVR		.014	.026	.120	.575	.403
WM		-.098	.104	-.248	-1.035	.282
Language		.064	.028	.695	2.657	.020

Note: NVR = non-verbal reasoning; WM = working memory; Language = structural language (1/2 grammar and 1/2 vocabulary).

Table 7. *Summary of the regression coefficients for the scores of the components of group 1 in the TEC (External) within the DS group and the TD group (bootstrap results based on 1000 bootstrap samples).*

			DS (n=22)			
Predictor	ΔR^2	***B***	**SE B**	β	***t***	***p***
Step 1	.076					
Constant		1.652	.477		3.432	.007
NVR		.033	.024	.275	1.279	.160
Step 2	.248					
Constant		.919	.598		1.817	.153
NVR		.008	.021	.065	.317	.696
WM		.136	.048	.540	2.638	.013
Step 3	.006					
Constant		1.051	.739		1.715	.172
NVR		.015	.027	.124	.484	.540
WM		.161	.077	.637	1.993	.044
Language		-.009	.024	-.153	-.401	.695
			TD (n=22)			
Predictor	ΔR^2	***B***	**SE B**	β	***t***	***p***
Step 1	.031					
Constant		2.728	.271		11.111	.002
NVR		.008	.009	.175	.795	.218
Step 2	.069					
Constant		2.297	.473		5.311	.002
NVR		.004	.008	.096	.422	.319
WM		.039	.029	.274	1.205	.131
Step 3	.233					
Constant		1.800	.457		4.182	.009
NVR		-.005	.012	-.123	-.559	.455
WM		-.016	.040	-.109	-.432	.563
Language		.023	.011	.690	2.509	.074

Note: NVR = non-verbal reasoning; WM = working memory; Language = structural language (1/2 grammar and 1/2 vocabulary).

Table 8. *Summary of the regression coefficients for the scores of the components of group 2 in the TEC (Mental) within the DS group and the TD group (bootstrap results based on 1000 bootstrap samples)*

			DS (n=22)			
Predictor	**Δ*R*²**	***B***	**SE B**	***β***	***t***	***P***
Step 1	.084					
Constant		1.557	.491		3.412	.005
NVR		.033	.026	.290	1.356	.199
Step 2	.088					
Constant		1.140	.543		2.141	.052
NVR		.019	.027	.165	.728	.456
WM		.078	.046	.323	1.424	.086
Step 3	.261					
Constant		.312	.562		.581	.575
NVR		-.025	.026	-.222	-.945	.277
WM		-.076	.070	-.317	-1.080	.268
Language		.058	.020	1.006	2.881	.005
			TD (n=22)			
Predictor	**Δ*R*²**	***B***	**SE B**	***β***	***t***	***P***
Step 1	.033					
Constant		2.636	.470		6.111	.001
NVR		-.004	.019	-.051	-.226	.832
Step 2	.004					
Constant		2.463	.907		3.130	.016
NVR		-.005	.020	-.069	-.288	.725
WM		.016	.061	.063	.266	.750
Step 3	.063					
Constant		2.018	1.089		2.291	.071
NVR		-.014	.022	-.182	-.703	.417
WM		-.034	.064	-.135	-.452	.521
Language		.021	.021	.357	1.099	.305

Note: NVR = non-verbal reasoning; WM = working memory; Language = structural language (1/2 grammar and 1/2 vocabulary).

Table 9. *Summary of the regression coefficients for the scores of the components of group 3 in the TEC (Reflective) within the DS group and the TD group (bootstrap results based on 1000 bootstrap samples).*

			DS (n=22)			
Predictor	ΔR^2	***B***	**SE B**	***β***	***t***	***p***
Step 1	.219					
Constant		.218	.522		.364	.687
NVR		.075	.029	.468	2.369	.016
Step 2	.137					
Constant		-.521	.540		-.779	.328
NVR		.050	.032	.312	1.561	.128
WM		.138	.071	.402	2.012	.075
Step 3	.008					
Constant		-.733	.755		-.907	.309
NVR		.039	.047	.242	.975	.378
WM		.098	.098	.287	.921	.311
Language		.015	.034	.181	.489	.606
			TD (n=22)			
Predictor	ΔR^2	***B***	**SE B**	***β***	***t***	***p***
Step 1	.260					
Constant		.981	.325		2.599	.941
NVR		.039	.014	.510	2.652	.019
Step 2	.000					
Constant		1.037	.710		1.505	.137
NVR		.040	.016	.516	2.503	.008
WM		-.005	.055	-.020	-.099	.895
Step 3	.048					
Constant		.642	.941		.832	.464
NVR		.032	.019	.417	1.869	.041
WM		-.049	.067	-.194	-.755	.387
Language		.019	.019	.313	1.117	.283

Note: NVR = non-verbal reasoning; WM = working memory; Language = structural language variable (1/2 grammar and 1/2 vocabulary).