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# Relationship between Emotion Comprehension, Vocabulary, and Verbal Working Memory in Intellectual Developmental Disorders: Involvement of Verbal Reasoning Skills

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**Abstract**

This study investigated the role of language-related abilities in emotion comprehension among young people with non-specific intellectual developmental disorders (NS-IDDs). Forty children and adolescents with NS-IDDs completed tasks assessing emotion comprehension, receptive vocabulary, verbal reasoning skills, and verbal working memory. Results showed that emotion comprehension was better predicted by comprehension of abstract words and verbal working memory, and that these two predictors were themselves predicted by verbal reasoning skills. These results therefore suggest a link between emotion understanding and verbal reasoning, which could be mediated by abstract vocabulary and verbal working memory. These findings provide insight into the relationships between emotion comprehension and language-related abilities in NS-IDDs.

*Keywords:* emotion comprehension, vocabulary, intellectual developmental disabilities, verbal reasoning, verbal working memory

# Relationship Between Emotion Comprehension, Vocabulary, and Verbal Working Memory in Intellectual Developmental Disorders: Involvement of Verbal Reasoning Skills

The relationships between emotions and language are a topic of growing interest in developmental research, the idea being that language abilities support the development of emotional abilities (Denham, 2007). Language skills are thought to help children give meaning to their own feelings and emotions, thereby fostering comprehension of emotional concepts. Children with stronger verbal skills engage more with others, which provides them with more opportunities to experiment and develop their ability to understand others' emotional states (Pons et al., 2003). Relationships between emotions and language are, however, rarely studied in young individuals with intellectual developmental disorders (IDDs). These neurodevelopmental disorders are characterized by intellectual and adaptive limitations, including difficulties in language and impaired emotional abilities (APA, 2016). While lexical difficulties have been linked to emotion identification in this population (Hippolyte et al., 2008), less is known about emotion comprehension, another emotional ability that has been shown to contribute to adaptive functioning (Trentacosta et al., 2010). The present study therefore aimed to expand current knowledge about the relationships between language abilities and emotion comprehension in young people with IDDs.

Emotion comprehension can be defined as the ability to grasp the nature, causes, and consequences of one’s own emotions as well as those of others (Pons et al., 2004). According to Pons et al. (2004), emotion comprehension develops through nine components distributed across three phases. In the first, external phase (2-5 years), children learn to identify emotions, understand the situational causes of emotions, and grasp that time and memories impact the reactivation of emotions. In the second, mental phase (5-7 years), children learn to consider the influence of beliefs and desires on emotions, and to differentiate between real and falsely

expressed emotions. In the third, reflective phase (9-12 years), children develop the ability to understand how moral rules influence emotions, conceive mixed emotions, and how to regulate their emotions. This developmental schema has been evidenced in typically developing (TD) children using the Test of Emotion Comprehension (Pons & Harris, 2000), but only limited data are available regarding individuals with IDDs. Studies have mainly been conducted among individuals with Down syndrome, with results revealing lower levels of emotion comprehension in children, adolescents and adults with Down syndrome compared with TD children matched on developmental age (Amado et al., 2016; Vy et al., 2023). These difficulties in emotion comprehension may arise from deficits in language-related areas such as verbal skills and working memory (WM), which are frequently observed in Down Syndrome (Abbeduto et al., 2007; Daunhauer et al., 2014).

While receptive vocabulary and grammar skills have been identified as predictors of emotion comprehension in TD children (Andrés-Roqueta et al., 2021), results among individuals with Down Syndrome are more contrasted: Andrés-Roqueta et al. found that these skills only predicted the mental phase of emotion comprehension in adults, whereas Vy et al. (2023) observed a predictive role of receptive vocabulary for overall emotion comprehension level in adolescents. These findings nevertheless offer valuable insights into the impact of verbal abilities on emotion comprehension development in individuals with Down syndrome. WM has also been shown to influence emotion comprehension in both TD children (Morra et al., 2011) and adolescents with Down syndrome (Amado et al., 2016). This contribution of WM can be attributed to the fact that emotion comprehension requires the integration and manipulation of various types of information (i.e., semantic knowledge about emotions and mental states, information relative to external events or context) to build complex representations of the emotions felt by oneself or others. Regarding these previous studies, two modifications have been proposed here. First, data were mainly collected from

participants with Down syndrome, a population that only represents approximately 15% of IDD cases (Maia et al., 2021). Thus, the choice was made here to focus on a population less studied in the literature, namely people with IDD without specific etiology (or non-specific IDD; NS-IDD), who nevertheless represent 35 to 40% of IDD cases (INSERM, 2016). Secondly, WM has been studied specifically through its verbal component (verbal working memory, VWM), assuming that understanding emotions mainly requires the manipulation of verbally encoded information.

Thus, emotion comprehension involves WM and vocabulary skills, yet the precise mechanism remains unclear. A proposed explanation would be to consider the potential contribution of verbal reasoning (i.e., ability to use language to solve a problem) in this process. According to Polk and Newell (1995), when people encounter a problem, they tend to rely more on linguistic skills than on logical skills to solve it. More specifically, they simplify the linguistic form of the problem using a range of reasoning mechanisms (e.g., deduction/induction, categorization, or relational reasoning), which then allow them to apply simple logical rules: this process corresponds to verbal reasoning. In the case of emotion comprehension, the problem for children is to understand the causes and consequences of their emotions or those of others. Generally, they are confronted with a lot of knowledge resulting from direct observation of the present situation (e.g., *I am waiting for my turn in the queue of the school canteen, there are a lot of people, I am being pushed into all senses, I see someone appear in front of me, he was not there before, I feel angry*). To understand their emotions, simplifying the form of the situation to reach a simpler linguistic form (e.g., *someone is overtaking my turn in the queue*) to which they can apply their semantic knowledge about emotions (e.g., *what makes me angry is violence, injustice, disrespect*) could help them to resolve the problem (e.g., *in fact, I have just been overtaken my turn in the queue and it is unfair, that's why I'm angry!*). This verbal reasoning process may involve

categorization skills, in that the experienced situation must be categorized as a prototype of situations known to typically generate a specific emotion. This process may also be supported by vocabulary skills that allow to change the linguistic form of the problem (e.g., here, to move from *"I see someone appear in front of me, he wasn't there before"* to *"someone is overtaking me in the queue"* to *"it's a situation of injustice"*). However, some types of words comprehension may be more involved in this process than others.

Indeed, research has demonstrated that vocabulary is not monolithic: different types of words have different developmental trajectories. Borghi et al. (2017) hypothesized that *concrete words*, referring to entities directly perceptible through our senses, are mainly acquired through sensorimotor experiences, whereas *abstract words* referring to entities with no easily perceptible referents are mainly acquired through linguistic experiences. As children first encounter sensorimotor experiences, concrete words are acquired before abstract ones. *Emotional words* occupy an intermediate position, as they may be associated either with experiential information, insofar as they refer to states that can be observed and experienced, or with linguistic information, insofar as they allow internal states to be labeled (Altarriba et al., 1999). Declercq et al. (2019) demonstrated in TD children that concrete words are acquired earlier than emotional words, which in turn are acquired earlier than abstract words. Subsequently, Declercq and Pochon (2022) showed a similar pattern in adolescents with Down syndrome. The same pattern of results should be observed in children and adolescents with NS-IDD, which would allow to consider different relations between vocabulary and emotion comprehension depending on the type of word. More precisely, considering that understanding emotions involves a verbal reasoning process, both abstract and emotional words should have a more important role than concrete words. Indeed, the abstract words would make it possible to simplify the form of the situation into a prototype of situation eliciting emotion (e.g. it is a situation of *injustice*) and this prototypical situation would then

be compared to the semantic emotional knowledge supported by the emotional vocabulary (e.g., injustice makes me *angry*).

Thus, the current study was intended to shed further light on the relationships between emotion comprehension, vocabulary skills, and VWM in NS-IDDs, adding a new variable of interest: the verbal reasoning skills. In this aim, predictors of emotion comprehension were investigated, hypothesizing that verbal reasoning skills are predictors of emotion comprehension, as well as VWM and word comprehension. More precisely, the comprehension of emotional and abstract words should contribute more to emotion comprehension than that of concrete words.

## Methods

### Ethics

The present noninvasive study was conducted in accordance with the principles of the Declaration of Helsinki. All parents provided their written consent for their child's participation. Children's oral assent was also collected before each session. Participants were tested by a licensed psychologist (MV) in compliance with the Code of Ethics for Psychologists (French National Consultative Commission of Ethics for Psychologists). All data were pseudonymized, and confidentiality was respected.

### Participants

Forty participants (21 boys and 19 girls) aged 8-16 years ($M$ = 13.3, $SD$ = 1.11) were recruited from three special schools in northeast France between September 2021 and March 2022. Psychologists of each structure identified participants who met the study inclusion criteria: 1) having an IDD and 2) reaching an elementary level of receptive and expressive skills in French language. Were excluded participants who were diagnosed a comorbid sensory, psychiatric or physical disability, as well as participants who received a comorbid

autism spectrum disorder diagnosis. Participants' intellectual and adaptive functioning was assessed to ensure that they all met the criteria for IDD (APA, 2016): intellectual functioning was assessed using the Wechsler Intelligence Scale for Children-5$^{th}$ Edition (WISC-V; Wechsler, 2016), and adaptive functioning through interviews with each participant's form tutor, using the Vineland-II (Sparrow et al., 2015) (see descriptive statistics in Table s1, Supplementary Materials).

Based on an effect size of $\beta$ = .278 for working memory and $\beta$ = .481 for language skills (a composite score of receptive grammar and vocabulary skills) from Andrés-Roqueta et al. (2021), a power analysis was conducted using G*power 3.1 for alpha = 0.05 and power = 0.80. Respectively, results indicated a required sample size of approximatively $N$ = 41 and $N$ = 25. As no study has already been conducted testing the predictive role of verbal reasoning on emotion comprehension, we settled to those effect sizes. Therefore, our sample size seems acceptable to detect the contribution of working memory, vocabulary and verbal reasoning skills on emotion comprehension.

**Materials and Procedure**

Participants were individually met twice at their school in a quiet room with no visual distractions. During the first session, lasting 30-90 minutes, the intellectual assessment was performed using the WISC-V. Only results from the Similarities and Digit Span subtests were used. During the second session, lasting 30-45 minutes, participants performed emotional tasks, including the vocabulary task and the Test of Emotion Comprehension.

The Similarities subtest (Wechsler, 2016), which assesses verbal reasoning skills, requires participants to explain what makes two words similar (e.g., "How are spoon and fork similar?"). It includes 23 items of increasing complexity all scored 0, 1, or 2 according to predefined answers provided in the instruction manual. The task stops after three consecutive 0 scores.

The Digit Span subtest (Wechsler, 2016) assesses VWM with items consisting of number sequences read aloud by the examiner. Participants have to repeat each sequence in either the same order (forward phase), reverse order (backward phase), or ascending order (sequence phase). Each phase includes 9 items that gradually increase in sequence length from 2 to 9 numbers, and stops after two consecutive wrong answers. Each phase is scored from 0 to 18 with an overall score ranging from 0 to 54.

The vocabulary task developed by Declercq et al. (2019) assesses the comprehension of 48 concrete, emotional or abstract words (i.e., 16 items per type of word) belonging to the lexicon of 4- to 7-year-old TD children. *Emotional words* refer to four basic emotions: happiness, sadness, anger, and fear. For each item, participants are shown four pictures, and asked to pick the one corresponding to a word pronounced by the examiner. An overall score is calculated, ranging from 0 to 48 (0-16 per type of word).

The TEC (Pons et al., 2000) assesses emotion comprehension in children aged 3-11 years, by measuring its nine components (see Introduction for description of three emotion comprehension phases). Each item consists of a short story illustrated with drawings. Participants are shown four pictures representing different emotional facial expressions and asked to pick the one corresponding to the emotion felt by the protagonist. Each of the nine emotion comprehension components is assessed through 1 to 5 story items and is scored out of 1, with a total score ranging from 0 to 9.

## Results

Analyses were initially conducted in two steps: 1) mean comprehension scores for the three word types (i.e., concrete, emotional, and abstract) were compared using Friedman's test and the Durbin-Conover test to ensure that Pochon and Declercq's results on people with Down Syndrome are also found in our sample of NS-IDD's participants ; 2) a correlation analysis was conducted, followed by a multiple stepwise regression analysis, to identify the

best predictors of emotion comprehension among the three types of word comprehension, VWM, and verbal reasoning skills. Regarding the results of the latter regression analysis, a third and final step has been added, which consisted of two other regression analyses, performed to further explore the role of verbal reasoning skills on emotion comprehension.

**Vocabulary task**

Comparison of mean comprehension scores between the three types of word revealed a significant effect, $\chi^2(2) = 32.6$, $p < .001$. Pairwise comparisons using the Durbin-Conover test showed that participants recognized concrete words ($M = 12.6$, $SD = 1.89$) more correctly than either emotional ($M = 10.03$, $SD = 3.21$; Durbin-Watson, $DW = 4.95$, $p < .001$) or abstract ($M = 9.13$, $SD = 3.23$; $DW = 7.16$, $p < .001$) words, and recognized emotional words more correctly than abstract words ($DW = 2.21$, $p = .03$). These results confirm the interest of distinguishing three type of word comprehension in NS-IDD's sample as they may have a different impact on emotion comprehension.

**Predictors of emotion comprehension**

The correlation analyses (see Table 1) indicated that emotion comprehension was positively correlated with verbal reasoning ($r = 0.37$, $p = .019$), VWM ($r = 0.55$, $p < .001$), and concrete ($r = 0.33$, $p = .041$), emotional ($r = 0.53$, $p < .001$) and abstract ($r = 0.61$, $p < .001$) word comprehension. Emotion comprehension did not correlate with chronological age ($r = 0.14$, $p = 0.386$).

We ran a multiple regression analysis to test for the prediction of emotion comprehension's scores, with chronological age and sex entered at Step 1, and VWM, verbal reasoning, and word comprehension scores entered stepwise at Step 2. Results at Step 1 showed that only 6% of the variance in emotion comprehension's score was explained by chronological age and sex, with nonsignificant results, $F(2, 37) = 1.17$, $p = .321$. At Step 2, the explained variance increased significantly to 46.7%, $F_{variation}(1, 37) = 11.78$, $p = .001$, with

two contributing predictors: comprehension of abstract words ($\beta$ = 0.50, $p$ < .001) and VWM ($\beta$ = 0.41, $p$ < .001) (see Table 2). Contrary to our initial assumptions, verbal reasoning skills did not predict emotion comprehension. Subsequent analyses therefore further explored the role of verbal reasoning skills on emotion comprehension.

**Predictors of abstract word comprehension and VWM: the role of verbal reasoning skills**

As mentioned before, verbal reasoning was positively correlated with emotion comprehension ($r$ = 0.37, $p$ = .019), but did not predict it. Moreover, verbal reasoning was positively correlated with VWM ($r$ = 0.39, $p$ = .014) and abstract word comprehension ($r$ = 0.45, $p$ = .003), which have both emerged as significant predictors of emotion comprehension. This led us to consider that the correlation between verbal reasoning and emotion comprehension may be due to a predictive role of verbal reasoning skills on both VWM and abstract word comprehension. To test this exploratory hypothesis, two stepwise multiple regression analyses have been conducted, the first one conducted on VWM scores and the second one on abstract word comprehension. For each multiple regression analysis, sex and chronological age were entered at Step 1, and verbal reasoning was entered stepwise at Step 2.

Results of the first regression analysis revealed that verbal reasoning was the sole significant predictor of 12.7% of the variance in VWM scores, $F$(1, 38) = 6.66, $p$ = .014; $\beta$ = 0.39, p = .014 (see Table 3). The second regression analysis revealed that 25.4% of the variance in abstract word comprehension scores was predicted by two variables, $F$(2, 37) = 7.65, $p$ = .002): sex ($\beta$ = 0.30, $p$ = .038) and verbal reasoning ($\beta$ = 0.39, $p$ = .009) (see Table 4).

## Discussion

The present study was intended to extend knowledge about language-related abilities that contribute to emotion comprehension in individuals with NS-IDDs. The relationships

between emotion comprehension, vocabulary, VWM, and verbal reasoning skills were explored. Preliminary results showed that participants with NS-IDDs understood concrete words better than emotional and abstract ones and understood emotional words better than abstract ones. Afterwards, the main results showed that VWM and abstract word comprehension were the best predictors of emotion comprehension, and that they were themselves predicted by verbal reasoning skills.

The preliminary results concerning the vocabulary task were consistent with previous studies among TD children and young participants with Down syndrome (Declercq et al., 2019; Declercq & Pochon, 2022): adolescents with NS-IDDs understood concrete words better than emotional and abstract ones, and emotional words better than abstract ones. This result confirms the importance of considering word type when studying the receptive vocabulary skills of individuals with NS-IDDs. In view of Declercq and Pochon (2022)'s results, future studies should more closely examine the developmental trajectory of each type of word comprehension in this specific population, for if the trajectories for emotional and abstract words differ between TD children and adolescents with Down Syndrome, this may also be the case for children and adolescents with NS-IDDs. Such findings could lead authors to reconsider the methodologies that are currently used to study IDD, which involve matching individuals with NS-IDDs and TD children according to their supposed developmental age. Most of the time, the latter is assessed with vocabulary tasks that do not distinguish between different types of word comprehension, implying that the development of concrete, emotional and abstract lexicons follows the same time course in both populations. Further research is therefore needed to determine whether the matching method based on vocabulary level is still relevant.

The main results of this study showed that emotion comprehension level was predicted by VWM and abstract word comprehension, but not by emotional word comprehension or

verbal reasoning skills, contrary to our initial assumptions. The influence of VWM on emotion comprehension was in line with previous studies (Morra et al., 2011), but whereas these studies did not distinguish between the verbal and visual components of WM, the current study exclusively considered the verbal component of WM, as we assumed that emotion comprehension mainly requires the manipulation of verbally encoded information about emotions. Results were consistent with this assumption, but future studies should go one step further and determine the specific roles of verbal and visual components of WM in emotion comprehension. Results concerning the role of abstract word comprehension echoe previous research showing that emotions are involved in abstract vocabulary acquisition (Ponari et al., 2020): here, it is the abstract vocabulary comprehension that emerged as being involved in emotional skills. These results add new arguments to the interplay of language and emotions in both typical and atypical development. However, comprehension of emotional vocabulary did not predict emotion comprehension, contrary to our initial assumptions. These results also contradict Ornaghi et al. (2013)'s observations but differences in the studied sample (TD children *versus* children and adolescents with NS-IDDs) may account for this divergence: as verbal skills are frequently limited in children and adolescents with NS-IDDs, their emotion comprehension may rely less on emotional words than it does in TD children. Additionally, Ornaghi et al. did not explore the influence of different types of vocabulary, only the contribution of emotional vocabulary. Considering the type of word comprehension could therefore be relevant for future studies investigating the impact of vocabulary skills on emotion comprehension development.

Finally, the main goal of this study was to explore the influence of a new variable, never considered before, on emotion comprehension: the verbal reasoning skills. If results showed a significant and moderate correlation with emotion comprehension, as mentioned before, verbal reasoning skills did not emerge as a direct predictor of this ability. However, they

emerged as being a direct predictor of both VWM and abstract word comprehension, that are themselves predictors of emotion comprehension. These results led to consider the hypothesis of a link between emotion comprehension and verbal reasoning skills which could be mediated through VWM and abstract vocabulary. The limitation of our sample size prevented us from running the relevant statistics (i.e., mediation analyses) but considering this hypothesis could be relevant for future studies. Although the predictive role of verbal reasoning on vocabulary may seem counterintuitive, this relationship has already been highlighted in the recent literature (Nahavandi et al., 2020). One way of explaining this link could rely on the fact that knowing a word is not dichotomous per se (i.e., knowing versus not knowing) and does not solely consist in learning its definition. Word knowledge is incremental and involves different levels of knowledge (Anderson & Ortony, 1975, and Nagy & Scott, 2000, as cited in Wagner et al., 2007). For example, Beck et al.'s (1987) model assumes that a child can have a contextual knowledge of a word (level 3) which allows him/her to understand this word when used in a specific situation without succeeding in using it or understanding it in another context. But the child can also have a rich and decontextualized knowledge of a word (level 5) which allows him/her not only to understand and use it out of context, but also to be able to extract the invariants of the reality to which it refers in order to create a new meaning, as in the metaphor (e.g., understanding the metaphor "*This city is an anthill*" requires understanding that an anthill is a place with a large population and sustained activity, just like metropolises). The transition from contextual knowledge to decontextualized knowledge of the word requires cognitive processes related to verbal reasoning such as abstraction, categorization, and generalization of knowledge. Therefore, verbal reasoning could predict the comprehension of abstract words by being directly involved in their acquisition. The implementation of verbal reasoning processes needed to acquire new meaning of words are made possible through multiple occurrences of

these words in different contexts. Indeed, recent research has shown that abstract meanings are mainly acquired through linguistic experiences (Borghi et al., 2017). Furthermore, the ability to reason about a word to acquire a rich semantic representation makes it possible to improve its memorization (Lockhart & Craik, 1990), which could explain the predictive role of verbal reasoning on VWM.

These results allow us to begin thinking about how the child could understand the causes and consequences of emotions in context. Moreover, the relationship between emotion comprehension and language-related abilities seems relevant to further explore in atypical development, especially for children and adolescents carrying NS-IDDs. It will nevertheless need to be tested on a larger sample to be able to carry out the appropriate statistical tests. Furthermore, a comparison with neurotypical children would be interesting to conduct in order to enrich our understanding of emotion comprehension. Moreover, it is important to keep in mind the limitations inherent in using the TEC for assessing emotion comprehension. Indeed, even if this task aims to limit children's verbal production, it nevertheless requires verbal comprehension and VWM skills to understand and process the emotional scenarios. It could have been of interest to resort on tasks requiring less verbal comprehension skills, as done in other DS studies (Barisnikov et al., 2020; Hippolyte et al., 2009) in which emotional scenarios were exclusively presented through images, unlike TEC which systematically associates images with verbal descriptions of emotional situations. However, removing the verbal component does not seem to have any influence on the assessment of emotion comprehension since in studies using non-verbal tasks, participants with DS still have difficulties in understanding emotions compared to TD children with the same level of language development (assessed using the EVIP). Therefore, using the TEC remains a relevant choice since it is a validated tool widely studied in the literature (with TD children and children with a neurodevelopmental disorder). In addition, the TEC has the advantage of

being designed on the basis of a developmental theoretical model which highlights different levels of complexity in understanding emotions, which is not the case of other non-verbal tasks (e.g., the TEC allows to take into account the influence of the characters' mental states to understand their emotions, while the other non-verbal tasks assess a more basic emotion comprehension by only asking participants to make the link between the external events of the situation and the characters' emotions). A second limitation of the TEC lies in the use of only four basic emotions, which restricts the exploration of this emotional competence: an update of the tool, including a broader variety of emotions, could be beneficial for future research.

In practice, the findings of this study emphasize that the emotion comprehension difficulties observed in individuals with NS-IDDs are not purely emotional, but involve other cognitive functions, such as language-related abilities. Considering these functions in the assessment and treatment of individuals with NS-IDDs should therefore be of key interest for professionals working in this area, enabling them to adapt their practice and offer more targeted remediation.

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**Declaration of interest statement**

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## Appendices

Table 1

*Correlation Matrix between Emotion Comprehension (EC), Chronological Age (CA), Verbal Reasoning (VR), Verbal Working Memory (VWM) and Concrete, Emotional and Abstract word Comprehension*

| | | CA | EC | VR | VWM | Concrete words | Emotional words | Abstract words |
|---|---|---|---|---|---|---|---|---|
| **CA** | Pearson's *r* | - | | | | | | |
| | *p* value | - | | | | | | |
| **EC** | Pearson's *r* | 0.141 | - | | | | | |
| | *p* value | 0.386 | - | | | | | |
| **VR** | Pearson's *r* | 0.550 | 0.369 | - | | | | |
| | *p* value | < .001 | 0.019 | - | | | | |
| **VWM** | Pearson's *r* | 0.254 | 0.550 | 0.386 | - | | | |
| | *p* value | 0.114 | < .001 | 0.014 | - | | | |
| **Concrete words** | Pearson's *r* | 0.306 | 0.325 | 0.521 | 0.262 | - | | |
| | *p* value | 0.055 | 0.041 | < .001 | 0.103 | - | | |
| **Emotional words** | Pearson's *r* | 0.216 | 0.528 | 0.524 | 0.281 | 0.424 | - | |
| | *p* value | 0.181 | < .001 | < .001 | 0.079 | 0.006 | - | |
| **Abstract words** | Pearson's *r* | 0.186 | 0.613 | 0.452 | 0.291 | 0.495 | 0.659 | - |
| | *p* value | 0.251 | < .001 | 0.003 | 0.069 | 0.001 | < .001 | - |

Table 2. *Results of Multiple Regression Analysis examining effects of Verbal Reasoning, Verbal Working Memory (VWM), and Concrete, Emotional and Abstract Word Comprehension on Emotion Comprehension, controlling for Chronological Age (CA) and Sex*

| | *Variables* | *B* | *SE B* | *β* |
|---|---|---|---|---|
| *Step 1* | Sex | 0.783 | 0.626 | 0.199 |
| | CA | 0.012 | 0.014 | 0.142 |
| *Step 2* | Sex | 0.779 | 0.625 | 0.198 |
| *Step 3* | Abstract word comprehension | 0.377 | 0.079 | 0.613** |
| *Step 4* | Abstract word comprehension | 0.305 | 0.073 | 0.495** |
| | VWM | 0.147 | 0.043 | 0.406** |

Table 3. *Results of Multiple Regression Analysis examining effect of Verbal Reasoning on Verbal Working Memory, controlling for Chronological Age (CA) and Sex*

| | *Variables* | *B* | *SE B* | *β* |
|---|---|---|---|---|
| *Step 1* | Sex | 1.279 | 1.708 | 0.118 |
| | CA | 0.060 | 0.037 | 0.255 |
| *Step 2* | CA | 0.060 | 0.037 | 0.254 |
| *Step 3* | Verbal reasoning | 0.329 | 0.127 | 0.386* |

Table 4. *Results of Multiple Regression Analysis examining effect of Verbal Reasoning on Abstract Word Comprehension, controlling for Chronological Age (CA) and Sex*

| | *Variables* | *B* | *SE B* | *β* |
|---|---|---|---|---|
| *Step 1* | Sex | 2.452 | 0.949 | 0.384* |
| | CA | 0.026 | 0.021 | 0.188 |
| *Step 2* | Sex | 2.444 | 0.957 | 0.383* |
| *Step 3* | Sex | 1.935 | 0.902 | 0.303* |
| | Verbal reasoning | 0.196 | 0.071 | 0.390** |

*Note.* * $p < .05$. ** $p < .01$.

## Supplementary materials

*Table s1. Description of Sample*

| | *N* | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| **Chronological age (in months)** | 40 | 159.05 | 23.31 | 98 | 195 |
| **Total IQ** | 40 | 58.85 | 8.75 | 44 | 75 |
| **Composite score for adaptive behavior** | 38 | 53.47 | 23.12 | 20 | 95 |
| **TEC score (EC)** | 40 | 5.72 | 1.99 | 2 | 9 |
| **Similarities score (VR)** | 40 | 16.63 | 6.43 | 0 | 27 |
| **Digit Span score (VWM)** | 40 | 10.93 | 5.47 | 2 | 29 |
| **Concrete word comprehension** | 40 | 12.60 | 1.89 | 8 | 16 |
| **Emotional word comprehension** | 40 | 10.03 | 3.21 | 3 | 15 |
| **Abstract word comprehension** | 40 | 9.13 | 3.23 | 3 | 15 |

*Note.* IQ: intellectual quotient; TEC: Test of Emotion Comprehension; EC: emotion comprehension; VR: verbal reasoning; VWM: verbal working memory.