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Reading comprehension resiliency in adolescents with and without dyslexia relates to vocabulary, listening comprehension and socioeconomic status

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STRUCTURED ABSTRACT

Background: Individuals with dyslexia are at risk of poorer reading comprehension levels due to their reading fluency impairment. However, some of such individuals exhibit a resilient profile, achieving appropriate reading comprehension levels despite their impairment.
Aims: This study aimed to investigate how key cognitive skills, specifically vocabulary and listening comprehension, may contribute to reading comprehension resiliency (RCR) in adolescents with dyslexia, especially in the face of disadvantaged socioeconomic status (SES).
Sample: Adolescents with dyslexia ($n = 56$) and without dyslexia ($n = 39$) averaging 16 years old were recruited.
Methods: Participants were assessed on their phonological skills, oral reading fluency, reading and listening comprehension, vocabulary skills, and SES. These variables were analysed using double mediation modelling.
Results: Individuals with dyslexia exhibited higher reading comprehension resiliency (RCR) index scores, indicating stronger resilience in reading comprehension development in relation to their poor reading fluency. RCR was associated with semantic abilities, including vocabulary skills and listening comprehension. A double mediation model was consistent with the idea that vocabulary skills might influence listening comprehension ability, which in turn may influence RCR. SES was also indirectly associated with listening comprehension ability through vocabulary.
Conclusions: Firstly, the results suggest that in the face of reading fluency impairments, semantic abilities might contribute to appropriate reading comprehension levels. This is a promising hypothesis for understanding RCR in dyslexia. Second, low SES should be considered as a possible indirect risk factor for RCR due to an association found with weaker vocabulary. Third, considering the total indirect influence of SES on RCR and its particular prominence for individuals with dyslexia, SES may be a more critical factor in managing and understanding dyslexia.

1. Introduction

Developmental dyslexia is a specific learning impairment with a neurobiological origin that affects reading fluency, word decoding, and spelling (American Psychiatric Association, 2013; Lyon, Shaywitz, & Shaywitz, 2003). Recently, a multi-deficit model of dyslexia that posits that dyslexia arises from multiple interacting risk and protective factors across genetic, neurobiological, cognitive, and environmental domains, rather than a single causative deficit has been adopted to account for the mechanisms causing the observed reading difficulties (Carroll et al., 2024; Pennington, 2006). However, a cognitive deficit in the ability to access, process, and manipulate speech sounds, otherwise known as a phonological processing deficit, still remains the most prominent etiological view that explains these difficulties (Carroll et al., 2024; Ramus et al., 2003; Vellutino, Fletcher, Snowling, & Scanlon, 2004). Although consistent evidence linking phonological processing deficits to difficulties in acquiring reading and spelling skills across various languages and orthographies has been reported in the literature, phonological

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processing deficits do not fully explain the variability observed in dyslexia, indicating the involvement of multiple factors (Carroll et al., 2024). In addition to cognitive risk factors, environmental factors such as Socioeconomic Status (SES), which refers to a combination of income, occupation, and education level (Baker, 2014), has also been crucially identified as having an impact both on reading acquisition (Fluss et al., 2009) and in modulating how dyslexia is behaviourally expressed in low SES families (Bishop, 2015). Indeed, Bishop (2015) suggests that growing up in a low SES family may pose a developmental risk to children prone to developing dyslexia or exacerbate already-recognized dyslexia.

According to the simple view of reading (Gough & Tunmer, 1986), reading comprehension level is equal to the product of decoding skills and listening comprehension. As phonological processing deficits make it difficult for individuals with dyslexia to decode and recognize words, which can impact reading fluency and create a bottleneck in constructing meaning from text (Pedersen, Fusaroli, Lauridsen, & Parrila, 2016; Simmons & Singleton, 2000; Snowling, Hayiou-Thomas, Nash, & Hulme, 2020). Therefore, it could be assumed that individuals with dyslexia (or at least the majority of them) would demonstrate difficulties in reading comprehension due to the continued presence of deficits in reading fluency which is predominantly linked to phonological decoding skills (Share, 1995). In these cases, reading comprehension difficulties would be considered as a secondary deficit resulting from difficulties in reading fluency (Fletcher, 2006; Vellutino et al., 2004). Even though difficulties in reading comprehension are often observed in individuals with dyslexia (Simmons & Singleton, 2000; Snowling et al., 2020) some studies have also reported a subset of intact reading comprehension abilities in some individuals with dyslexia, despite the presence of primary behavioural deficits, such as impairment in reading fluency and decoding (e.g., in French, see Cavalli et al., 2019; Dutch: see Law, Veispak, Vanderauwera, & Ghesquière, 2018; and English, see Law, Wouters, & Ghesquière, 2015).

1.1. Reading comprehension resiliency (RCR) in dyslexia

Although decoding and comprehension skills are usually found to be associated, an intriguing proportion of individuals with dyslexia have levels of reading comprehension skills that are higher than what could be predicted by their (relatively low) levels of decoding skills. This is typically recognized as Reading Comprehension Resiliency in the literature (hereafter RCR; Jackson & Doellinger, 2002). It has been argued that RCR may result from robust oral language skills in these individuals, in particular, strong semantic skills (Welcome, Chiarello, Halderman, & Leonard, 2009). Another way of understanding RCR may be through the consideration of developmental, functional strategy. In other words, one could ask what the functional benefit is of being resilient in reading comprehension over fluency. Indeed, it would be ideal for individuals with dyslexia to directly compensate for reading fluency difficulties, as this could lead, in theory, to the development of a satisfactory level of reading comprehension. However, compensating for reading fluency difficulties, as described in the compensatory framework (Livingston & Happé, 2017), has so far only been observed in a very limited number of individuals (Cavalli et al., 2018). In comparison, achieving improved comprehension (referred to herein as RCR) appears to be much more common (Lefèvre, Colé, Duncan, El Ahmadi, & Cavalli, in preparation). Moreover, the functional necessity of efficient oral reading fluency in everyday life arguably drops significantly after elementary school. In line with this change of developmental demands, individuals with RCR may prioritize reading comprehension over reading fluency. However, to date, limited research has explored cognitive abilities underlying RCR.

To address this gap and broaden our understanding of RCR, this study aimed to investigate the role of semantic abilities (i.e., vocabulary and listening comprehension) in predicting RCR in individuals with and without dyslexia, along with the potential impact of SES (i.e., measured by a composite score of parent education level and occupational status). To achieve this goal, this study adopted a quantitative approach where RCR was measured as a continuous variable. This approach directly follows from previous studies that have examined RCR as a continuous variable, often referred to as the RCR index (Farris, Cristan, Bernstein, & Odegard, 2021; Patael et al., 2018). Among these studies, the RCR index was formally calculated by subtracting an individual's decoding score (or reading fluency) from their reading comprehension level (Patael et al., 2018). This subtraction-based index, albeit simple, is known to offer a greater ease of interpretation and a directly relevant variable for clinical contexts and practice (Patael et al., 2018). The RCR index measures resiliency, i.e., the degree to which an individual has achieved reading comprehension despite deficits in reading fluency. Prior research has argued that this index is effective as a quantitative continuous measure that simultaneously reflects both comprehension and fluency (i.e., their difference), such that positive values reflect resiliency (high comprehension despite low fluency). Furthermore, based on additional research (e.g., Lefèvre et al., in preparation; Shaywitz, Escobar, Shaywitz, Fletcher, & Makuch, 1992) that has frequently observed the scores of reading comprehension and fluency in neurotypical and dyslexic readers to be organised on a continuum, this measure allows for the advantage of continuous statistical analyses (a greater use of the variance in the data, more integrative models) instead of being limited to dichotomous group analyses (e.g., *t*-tests). Herein, based on these arguments, and notably the capacity to account for other variables simultaneously, we model RCR, investigating its link to the cognitive variables of interest, as well as SES.

1.2. Achieving reading comprehension resiliency (RCR)

Past work examining how RCR is achieved has noted the interplay of various cognitive and linguistic abilities that allow individuals with dyslexia to comprehend text effectively despite having impaired reading fluency (Brèthes et al., 2022; Ransby & Swanson, 2003). Specifically, semantic abilities, notably vocabulary and listening comprehension skills, have been implicated in RCR. Research has consistently highlighted the importance of semantic abilities in reading comprehension (Fernandes, Querido, Verhaeghe, Marques, & Araújo, 2017; Foorman, Koon, Petscher, Mitchell, & Truckenmiller, 2016; Goodwin et al., 2021; Ransby & Swanson, 2003; Savage, 2006). For instance, a longitudinal study of 72 typical child readers by Nation and Snowling (2004) reported that vocabulary and listening comprehension predicted reading comprehension levels both concurrently and longitudinally, significantly more than phonological skills.

In the case of individuals with dyslexia, preserved vocabulary levels (Cavalli et al., 2016) and listening comprehension skills (de Oliveira, da Silva, Dias, Seabra, & Macedo, 2014) have been documented. These may thus contribute to compensate for deficits in decoding and reading fluency, facilitating better reading comprehension. In support of this, studies have shown that semantic abilities such as vocabulary and listening comprehension are better predictors of reading comprehension than reading fluency or decoding skills in typical and dyslexic adolescents and adult readers (Brèthes et al., 2022; Fernandes et al., 2017; Foorman et al., 2016; Goodwin, Petscher, & Reynolds, 2021; Jackson, 2005; Ransby & Swanson, 2003; Savage, 2006).

Among studies specifically investigating RCR, semantic skills have been found to play a significant role (Farris et al., 2021; Welcome et al., 2009, 2011). For example, Farris et al. (2021) demonstrated that RCR, quantified as a continuous variable, was directly associated with morphological awareness and mediated by vocabulary scores in typical adult readers. These results along with others (Welcome et al., 2009, 2011) highlight the importance of semantic skills in achieving RCR. Individuals with dyslexia who exhibit higher reading comprehension despite decoding deficits are often found to possess strong semantic skills. This suggests that focusing on the development and enhancement of semantic abilities can be a strategic approach to fostering RCR.

The investigation of RCR profiles among individuals with dyslexia represents a shift towards recognizing and understanding the heterogeneity within the dyslexic population. Most studies on dyslexia often overlook the diverse profiles present within this group. By focusing on specific profiles such as RCR, researchers can gain deeper insights into the various mechanisms that enable some individuals with dyslexia to achieve reading comprehension resiliency. This approach helps in understanding and describing the diversity of profiles naturally occurring within the dyslexic population. In the continuation of this important line of research, our study aims to investigate how several key cognitive skills, specifically, vocabulary and listening comprehension, contribute to the RCR profile, in the context of SES disadvantages. Previous studies have shown that these cognitive skills are both correlated and partially independent (Massonnié, Bianco, Lima, & Bressoux, 2019; Savage, 2006), underscoring their distinct contributions to reading comprehension. Building on Cutting and Scarborough's extended Simple View of Reading (2012), Colé et al. (2018) employed an exploratory, data-driven approach with a large sample of first-graders children from low-SES families to map the relationships between reading skills and linguistic components. Their findings demonstrated that vocabulary level is a significant predictor of listening comprehension. This supports the hypothesis that vocabulary and listening comprehension play a crucial role in achieving RCR.

1.3. Which risk factors can jeopardize the RCR?

A substantial body of research indicates that vocabulary, and early oral language skills in general, are significantly influenced by SES. Research highlights that the quality and quantity of linguistic interactions in early childhood are crucial for the development of reading skills and overall literacy (Hart & Risley, 1995; Korat, Klein, & Segal-Drori, 2007). Studies show that children from higher SES families are exposed to a greater diversity of words and more complex sentence structures, fostering richer vocabulary and better oral language skills (Carlie et al., 2024). Conversely, children from lower SES backgrounds may face limited exposure to such language-rich environments, contributing to a gap in language development that can persist into their school years and beyond (Carta, Greenwood, Baggett, Buzhardt, & Walker, 2012). These disparities in the oral language environment likely contribute to the observed associations between low SES and diminished language abilities, encompassing both vocabulary and verbal reasoning skills (Beitchman et al., 2008; Hart & Risley, 1995). Consequently, this places SES as a critical early predictor of verbal and spoken abilities, including early vocabulary acquisition (Bowey, 1995; Fernald, Marchman, & Weisleder, 2013; Walker, Greenwood, Hart, & Carta, 1994) and listening comprehension (Carlie et al., 2024).

Given the role that oral language and vocabulary play in predicting reading comprehension skills, it is plausible that SES may be indirectly associated with RCR through these primary oral language measures (e.g., listening comprehension and vocabulary levels). This issue is further compounded by the fact that children with dyslexia often struggle with phonological processing, a critical component of reading ability. When combined with the language deficits associated with low SES, these children are at an even greater risk for significant reading difficulties (Catts & Petscher, 2022; Kieffer, 2010). This dual burden can lead to a more pronounced gap in reading comprehension skills. Therefore, understanding the relationship between SES and the consequent reading comprehension levels found later in life in individuals with dyslexia is of particular importance.

1.4. Research gap and hypotheses

Given the past research examining the profiles of individuals with Reading Comprehension Resiliency (RCR) within the dyslexic population and the studies implicating the role of semantic skills and socioeconomic status (SES) in the achievement of RCR, this study aims to model the relationships between SES, vocabulary, listening comprehension, and reading comprehension resiliency as a continuous profile. Based on current literature, we have hypothesized a double mediation model, presented in Fig. 1. In this model, we hypothesize a direct link between listening comprehension and SES (path C'; Carlie et al., 2024), and that RCR is directly explained by vocabulary (E'; Welcome et al., 2009). We further hypothesize that the relationship between SES and listening comprehension is mediated by vocabulary (A-B; Beitchman et al., 2008), and that the direct effect of vocabulary on RCR is mediated by listening comprehension (B-D; Colé et al., 2018; Welcome, Leonard, & Chiarello, 2010).

2. Methods

2.1. Recruitment and participants

Two groups of adolescents participated in the study: one comprising 56 individuals diagnosed with dyslexia (DYS; 31 females and 25 males) and another consisting of 39 individuals without reading impairments (typical readers, TR; 30 females and 9 males). All participants were native French speakers. Inclusion criteria for the dyslexia group required a formal diagnosis from a certified health professional. Both written and oral informed consents were obtained from all participants and their parents, ensuring ethical compliance and participant autonomy. Participants were in 9th (n = 5), 10th (n = 42) and 11th grade (n = 37). Most participants were enrolled in standard school programs (n = 48), but a subset was enrolled in technical (n = 12) and vocational programs (n = 24). None of the participants had a history of head injury, nor did they exhibit hearing deficits or uncorrected visual impairments. All participants were right-handed. Groups (DYS & TR) were matched in chronological age (Age min = 12 years and 7 months; Age max = 18 years) and in non-verbal reasoning skills using the Matrix reasoning subtest of the Wechsler Intelligence Scale for Children, 5th ed. (WISC-V; Wechsler, 2016). None of the participants presented a score below the fifth percentile on this subtest, excluding individuals with an intellectual disability. In addition, vocabulary and verbal comprehension were measured with the Vocabulary and the Similarities subtests of the WISC-V (Wechsler, 2016), assessing both verbal concept formation and verbal abstract reasoning (respectively). None of the participants were below the 5th percentile. Therefore, individuals with a Developmental Language Disorder (DLD) were excluded, which is important given the high rate of co-morbidity between dyslexia and DLD (Bishop & Snowling, 2004). The presence of a phonological processing impairment was confirmed with a phonemic segmentation task and between-groups comparisons demonstrated a significant impairment among individuals with dyslexia. Descriptive statistics and group comparisons details are available in Table 1.

2.2. Materials and measures

Before conducting subsequent modelling that analyzes individuals with dyslexia and typical readers based on continuous measures of their reading skills, we first present a group comparison for each variable, including SES. This comparison, using two-tailed *t*-tests, contrasts individuals with dyslexia against typical readers to better characterize the samples (all group comparisons are presented in Table 1 and in each material subsection).

2.2.1. Vocabulary

Two tasks were used to assess participant vocabulary skills: the Vocabulary and Similarities subtests of the WISC-V battery (Wechsler, 2016). The vocabulary subtest is a production definition task with 30-word items. Words are presented orally by the experimenter and participants are instructed to define as accurately as they can. The similarities subtest consists of 23 pairs of words given orally by the experimenter, in which participants are tasked to find in what ways the

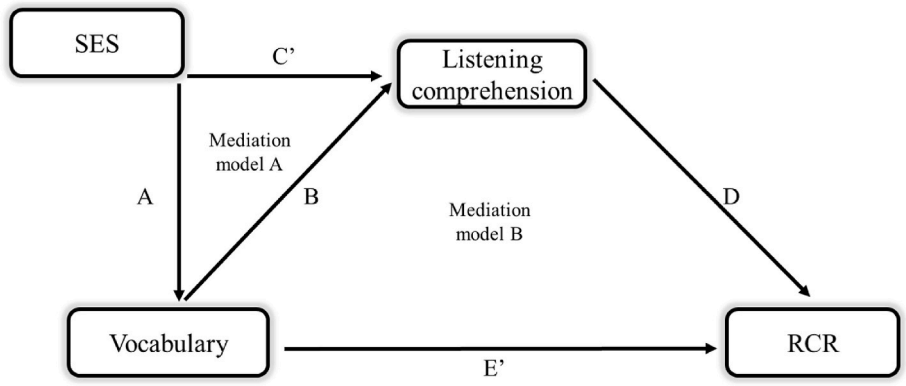


Fig. 1. Hypothetical structure of a double mediation between socioeconomic status (SES), listening comprehension, vocabulary, and reading comprehension resiliency (RCR). Direct paths, purposefully mediated, are marked with an apostrophe.

Table 1
Group characteristics (Mean and Standard Deviation), statistical comparison (Student's test) and effect size (Cohen's d) on assessed variables along with distribution characteristics (Shapiro test, Kurtosis and Skewness).

Variables	DYS n = 56 M (SD)	TR n = 39 M (SD)	*t*(93)	Cohen's *d*	Shapiro W	Kurtosis	Skewness
Inclusion variables							
Age in months	192.09 (10.19)	191.85 (12.27)	0.03 ns	0.01	1.00 ns	2.63	0.00
Non-verbal reasoning	9.21 (2.87)	10.15 (2.3)	−1.62 ns	−0.33	0.98 ns	2.61	−0.03
Phonemic segmentation Accuracy	24.27 (5.46)	26.71 (2.8)	−2.83 **	−0.59	0.98 ns	2.6	−0.07
Phonemic segmentation Mean Reaction Time	2311 (721)	1801 (473)	4.50 ***	0.93	1.00 ns	2.63	0.00
Similarities (Standard score)	10.84 (3.2)	12.03 (3.69)	−1.45 ns	−0.31	0.98 ns	2.57	0.01
Vocabulary (Standard score)	10.25 (2.5)	10.87 (2.99)	−1.07 ns	−0.23	0.98 ns	2.62	0.02
Modelling variables							
RCR index	0.32 (0.92)	−0.46 (0.93)	4.04 ***	0.85	0.99 ns	3.85	0.19
Listening Comprehension	9.36 (3.46)	9.54 (3.89)	−0.24 ns	−0.05	0.99 ns	2.63	0.00
Reading Comprehension	13.84 (6.09)	15.97 (6.34)	−1.49 ns	−0.31	0.99 ns	2.54	−0.04
Reading Fluency	322.35 (78.04)	440.45 (75.59)	−7.36 ***	−1.53	1.00 ns	2.63	0.00
Socioeconomic Status	67.66 (19.44)	68.18 (21.34)	0.12 ns	0.03	0.99 ns	2.61	−0.04
Vocabulary composite score	−0.13 (0.88)	0.19 (1.13)	−1.33 ns	−0.29	1.00 ns	2.60	0.01

Note. DYS: individuals with dyslexia; TR: typical readers; RCR: Reading Comprehension Resiliency. The *p*-value of the *t*-tests were two-tailed and performed on the transformed data with the non-paranormal transformation (Liu et al., 2009), as the distribution characteristics (Shapiro test, Kurtosis and Skewness). ***$p < 0.001$; **$p < 0.01$; ns $p > 0.10$).

two words relate to each other. For both subtests, we followed the procedure described in the WISC-V manual. The experimenter began with the word item corresponding to the participant's age (in our case above 12 years old) and stopped the test after 3 consecutive errors. Two points were given for an accurate answer and 1 point for a partial accurate answer. A composite score was calculated by averaging these 2 sub-tests.

The vocabulary subtest from the WISC-V showed no notable difference between individuals with dyslexia and typical readers ($t(93) = -1.06$, $p = .29$, score range = [5:18]) as well as the similarities subtest from the WISC-V ($t(93) = -1.63$, $p = .29$, score range = [5:19]). A correlation analysis revealed that both vocabulary scores were highly correlated ($r = 0.53$, $p < .001$). Additionally, we performed Explanatory Factor Analysis (EFA) to extract latent factors from the five measured variables, which included the vocabulary and similarities scores from the WISC-V, the listening comprehension scores, the RCR index, and the SES index. EFA results indicated that performances on both vocabulary subtests loaded heavily onto the same factor (i.e., verbal comprehension; vocabulary scores loading = 0.76; similarities scores loading = 0.9), while the other variables each loaded onto separate factors. The correlation and EFA analyses thus support the grouping of both vocabulary and similarities subtests within the same factor. We therefore created a composite vocabulary score by calculating the scaled mean of both scores. The comparison between individuals with dyslexia and typical readers remained non-significant ($t(93) = -1.52$, $p = .13$, score range = [−1.83, 2.52]).

2.2.2. *Reading fluency*

Reading fluency was assessed using the Alouette test (Lefavrais, 1965), which is a 265-word text that assesses oral reading fluency without context. It was selected because it is extensively used by French practitioners and researchers for dyslexia screening (Bertrand, Fluss, Billard, & Ziegler, 2010; Pourcin, Sprenger-Charolles, El Ahmadi, & Colé, 2016). Furthermore, robust psychometric validity has been demonstrated for the Alouette test (Cavalli et al., 2018). The text consists of real words in meaningless but grammatically and syntactically correct sentences which limits the reader's access to contextual information. The participants were asked to read out loud the text presented on a single A4 paper sheet as fast and as accurately as possible. Reading time along with the number of incorrectly read words was recorded. The test was stopped if the maximum time of 3 min was exceeded. Based on the accuracy score and the reading time, an efficiency score (i.e., CTL) was computed (Pourcin et al., 2016). We used the following formula: CTL = (A/RT)*180, where A = accuracy (self-corrections are considered as errors), and RT = reading time (maximum = 180 s). The between-group comparisons demonstrated a significant impairment

among individuals with dyslexia on the CTL score ($t(93) = -7.39$, $p < .001$, score range = [154, 605.26]).

2.2.3. Listening comprehension

The listening comprehension task required participants to listen to a short part of the book *Planet of the Apes* (Boulle, 1963) pre-recorded by a female reader and played by the experimenter. By the end of the story, the experimenter read 20 open-ended questions (10 inferential and 10 literal) to the participant who had to answer orally. On average, the text read by the experimenter consisted of 7 sentences by paragraph and 13.7 words per sentence. The task resulted in a Cronbach's alpha of 0.69 which corresponds to a moderate reliability (Brèthes et al., 2022). On average, listening comprehension was not different between individuals with dyslexia and typical readers ($t(93) = -0.23$, $p = .82$, score range = [1, 18]).

2.2.4. Reading comprehension

The task assessing reading comprehension was composed of three texts chosen from the French newspaper *Le Monde*. Each text was about the endangerment of the Australian great coral barrier. Twenty questions were then asked to participants. The question set was divided into two principal information modalities: 10 questions aiming for literal information (4 multiple choices and 6 open-ended) and 10 questions aiming for inferential information (5 multiple choices and 5 open-ended). The 3 texts had on average 2.8 sentences per paragraph and 26.3 words per sentence. A Cronbach's alpha of 0.78 was observed, indicating good reliability (Brèthes et al., 2022). On average, reading comprehension scores were not significantly different between individuals with dyslexia and typical readers ($t(93) = -1.64$; $p = .10$, score range = [2, 28]).

2.2.5. Socioeconomic status (SES)

Hollingshead Index (Hollingshead, 1975) was used to calculate the SES of the participant's family, which includes the parents' level of education (PE), occupation (PO), and the number of parents (e.g., 1 or 2 caregivers). In this index, parent education level is defined along 7 levels (1 = completed less than mandatory schooling and 7 = college degree obtention) and professional occupation along 9 levels (1 = factory worker or non-qualified worker and 9 = CEO or senior executive). The two scales used to determine level of education and type of professional occupation were retrieved from a translation toward European society (Genoud, 2011). As reported in Demir-Lira, Prado, and Booth (2016), SES was calculated using the following weights: *SES Index* = (PO x 7) + (PE x 4); in which PO was defined as the maximum of both parents and PE the mean of both parents. SES index did not differ between reading groups ($t(93) = -0.13$; $p = .89$, score range = [11, 91]).

2.3. Procedure

Participants were recruited with the cooperation and assistance of their school (e.g., middle/high schools). The study was advertised by teachers and through flyers. No monetary compensation was offered for the completion of the study, but the participants received explanatory feedback on the different tasks that they had to complete during the study. All the tasks were administered by the first author or master students in psychology trained and under the supervision of the first and the last author of this study. The participants were free to ask for a break in between the tasks which were administered in two independent sessions to avoid fatigue and increase motivation. The participants were asked to confirm their consent at each session. The SES data were collected through an online survey addressed to the participants' parents or guardian by email. A small number of parents and guardians preferred, by convenience, to answer the survey orally with the first author.

2.4. Data analysis

2.4.1. Missing data handling and normality assumptions

Regarding the SES variable, we report a small proportion of missing data points (n = 11/95). These missing values were considered to be missing at random. The R package *mice* (van Buuren & Groothuis-Oudshoorn, 2011) was used to impute the missing data via its algorithm consisting of multivariate chained equations using predictive mean matching. It was verified that the following statistical results/-conclusions remained unchanged when these participants were included versus removed from the analyses. Finally, as some variables were found to be non-normally distributed, the non-paranormal transformation (Liu, Lafferty, & Wasserman, 2009) was utilised. After the transformation, all distributions were confirmed by the Shapiro-Wilk test as gaussian (all $p > .05$, see Table 1).

2.4.2. Reading comprehension resiliency index and structural modelling

Path analyses were used to assess whether our data are compatible with the hypothesis that RCR is directly related to semantic abilities (specifically, vocabulary and listening comprehension) and indirectly related to SES. We further aimed to test whether our data are also compatible with the idea that SES may affect how these skills relate to RCR across all participants. Prior to calculating the RCR index, both the reading comprehension and reading fluency scores were standardised (z-scored). This operation was performed in order to prevent any possible scale effect biases from being introduced.

First, a standard multiple regression analysis (i.e., all independent variables are entered simultaneously) was carried out across all participants in order to assess if reading comprehension was associated with reading fluency with the following formula: Reading comprehension ~ Reading fluency*Group. Furthermore, the multiple regression analysis simultaneously allowed for verification as to whether any group difference in the relationship between reading fluency and reading comprehension was present, which was confirmed as absent. After the verifications, the index of RCR was calculated as the difference between reading comprehension and reading fluency.

We then implemented a path analysis (*lavaan* R package; Rosseel, 2012) in the form of a double mediation model, which simultaneously evaluated the direct and indirect relationships between the variables previously presented, as visualised in Fig. 1. The hypothetical model tested estimated 8 parameters (5 regressions and 3 residuals). In accordance with the simulation study of Jackson (2003), the ratio of 10 observations per parameter, recognized as a minimum to estimate a simple model, was respected as our analyses included 95 observations.

3. Results

3.1. Reading comprehension resiliency modelling (RCR)

First, we used a standard multiple regression to test whether reading comprehension was associated with reading fluency (Reading comprehension ~ Reading fluency*Group). That analysis showed that the interaction of group x reading fluency was not significant ($\beta = 0.02$, $SE = 0.25$ $t = 0.13$, $p = .89$), likewise the group effect was not significant ($\beta = -0.09$, $SE = 0.25$, $t = -0.68$, $p = .50$); though reading comprehension was partially explained by reading fluency ($\beta = 0.39$, $SE = 0.15$, $t = 2.54$, $p < .01$, see Fig. 2a), with a low Adjusted-R^2 of 0.11 explained variance. As reading comprehension was only marginally explained by reading fluency across groups, this analysis corroborates the interest of studying the link that other variables may have in RCR.

An RCR index was then calculated for each participant by computing the difference between their standardized reading comprehension score and standardized reading fluency score. A positive RCR index indicates higher reading comprehension than reading fluency, while a negative RCR index indicates the opposite (lower reading comprehension than reading fluency). To ensure the RCR index was distinct from reading

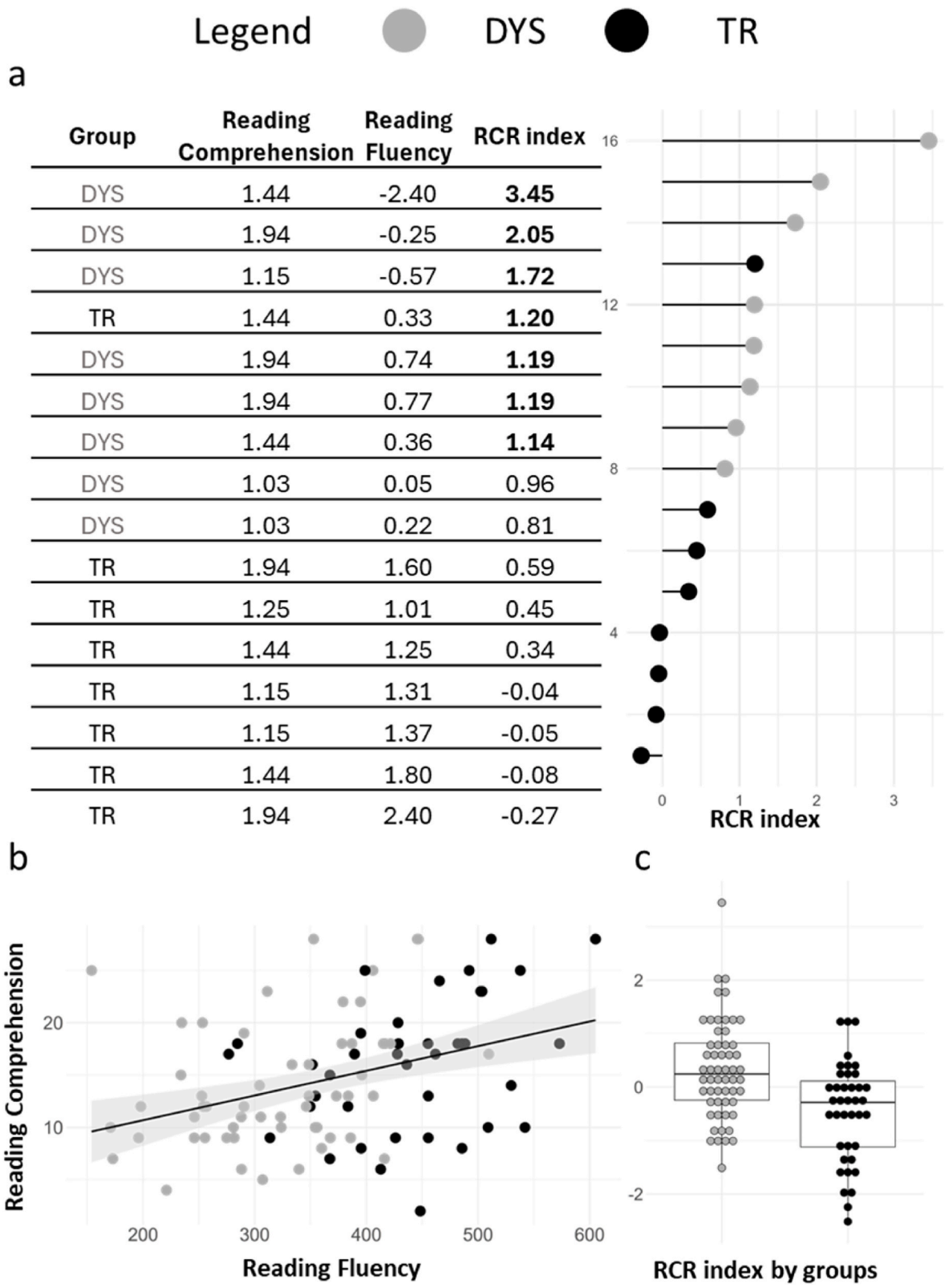


Fig. 2. Reading comprehension, Reading Fluency, and RCR score by group. (a) Summary table with good comprehenders and their scaled reading comprehension score, reading fluency score and RCR index (in bold the RCR index above 1 SD) (left), with a graphical representation of the magnitude of the RCR index (right). (b) Linear relationship (and standard error) between reading comprehension score and reading fluency. (c) Distribution by groups of the scaled reading comprehension resiliency index.

comprehension levels, we conducted a straightforward single-case analysis, confirming that participants with high reading comprehension levels did not necessarily exhibit high RCR values. Among the 95 participants, 16 had a reading comprehension score equal or superior to 1 SD above the mean (calculated across both samples), 8 individuals with dyslexia and 8 typical readers. Within this sub-sample of 16 good comprehenders, the RCR index differentiated them: 7 participants had an RCR index superior to +1 SD above the mean, 5 had an RCR ranging from +0.95 SD to +0.34 SD and 4 had an RCR index ranging from −0.04 SD and −0.27 SD (see group and score details in Fig. 2a). Hence, RCR is distinct from the reading comprehension score: good comprehenders do not necessarily exhibit a highly positive RCR.

There was a significant difference between individuals with dyslexia and typical readers with respect to the RCR index ($t(93) = 4.89$, $p < .001$, $d = 1.03$). As can be seen in Fig. 2b, individuals with dyslexia showed a greater RCR index compared to typical readers. This was expected by the definition of RCR (Jackson & Doellinger, 2002).

3.2. Correlation analysis

To study RCR as a continuous variable and assess the magnitude of all the relations before the mediation analysis, we combined both groups and performed a preliminary correlation analysis. All correlation coefficients and their degree of significance (corrected for multiple comparisons) are provided in Table 2. RCR was significantly correlated with vocabulary ($r = 0.26$; $p < .05$) and to listening comprehension ($r = 0.30$; $p < .01$). Listening comprehension was correlated with vocabulary ($r = 0.33$, $p < .01$). SES was correlated with both vocabulary ($r = 0.43$, $p < .001$) and listening comprehension ($r = 0.28$, $p < .01$).

3.3. Path analysis

A path analysis in the form of a double mediation model was then performed to assess whether our data was consistent with the hypothesized model relating vocabulary, RCR, SES, and listening comprehension (see Fig. 1). The path analysis, presented in Fig. 3, is composed of two serial mediation models. Dashed arrows represent direct effects while solid arrows represent indirect effects. A direct effect is said to be fully mediated when the beta coefficient in the mediation model is no longer significant in comparison with the prior correlation coefficient. The goodness of fit indices presented by the whole model are excellent given its performance on the standard SEM diagnostics as discussed by Hu and Bentler (1999) and Kline (2005; $df = 1$; $X^2 = 0.02$; $p = .89$; $SRMR = 0.004$; $RMSEA = 0.00$, $CI_{90\%} = [0.00; 0.13]$; $CFI = 1.00$; $TLI = 1.19$; $AIC = 776.06$). RCR was associated with listening comprehension (D: $\beta = 0.23$, $SE = 0.10$, $Z = 2.25$, $p = .024$) which was itself associated with vocabulary (B: $\beta = 0.27$, $SE = 0.10$, $Z = 2.68$, $p = .007$). The direct effect of vocabulary on RCR was fully mediated (E': $\beta = 0.19$, $SE = 0.10$, $Z = 1.87$, $p = .06$) by listening comprehension but the indirect effect, taking into account only vocabulary and listening comprehension, was not significant (B*D: $\beta = 0.06$, $SE = 0.04$, $Z = 1.72$, $p = .08$).

The second part of the path analysis was composed of a second mediation model testing the relationship between SES, vocabulary and listening comprehension. As stated above, listening comprehension was associated with vocabulary. Vocabulary itself was associated with SES (A: $\beta = 0.34$, $SE = 0.09$, $Z = 3.52$, $p < .001$). The direct effect of SES on listening comprehension (C': $\beta = 0.16$, $SE = 0.10$, $Z = 1.56$, $p = .12$) was fully mediated by vocabulary and the indirect effect was significant (A*B: $\beta = 0.09$, $SE = 0.04$, $Z = 2.13$, $p = .03$). In addition, the total indirect effect ((A*B*D)+(C*D)+(A*E)), representing the pathway from SES to RCR via all possible indirect paths (i.e., mediations with vocabulary and listening comprehension variables), was significant ($\beta = 0.12$, $SE = 0.05$, $Z = 2.53$, $p = .012$). This last result supports the interpretation of the total indirect effect as an indirect association between SES and RCR, as discussed in Hayes (2022).

As both direct effects were fully mediated, we tested an alternative nested model by removing the direct effects. The AIC from this simpler model was slightly higher than the initial model ($AIC = 777.94$) and the goodness of fit indices poorer ($df = 3$; $X^2 = 5.90$; $p = .12$; $SRMR = 0.08$; $RMSEA = 0.10$, $CI_{90\%} = [0.00; 0.22]$; $CFI = 0.93$; $TLI = 0.85$). Consequently, the initial model was retained as the final model. In addition, given our relatively small sample size, we also performed a bootstrapping on standard error of the SEM analysis ($n = 3000$). This analysis, which provides a more robust estimation of the model parameters and may reduce a possible bias due to the size of the sample, is presented in Table 3. The overall results of the bootstrapped model replicate our initial results.

4. Discussion

The main objective of the present study was to investigate the role of semantic abilities, specifically vocabulary and listening comprehension, in explaining Reading Comprehension Resiliency (RCR) in adolescents with dyslexia, associated with socio-economical status (SES). A group of 95 participants, including 56 adolescents diagnosed with dyslexia and 39 adolescents without reading impairments, were assessed on their phonological skills, oral reading fluency, reading and listening comprehension, vocabulary skills and SES. All of these variables were analysed conjointly via a double mediation/path modelling to test the hypothesis that RCR may be directly explained by semantic abilities, indirectly by SES, and that an association between SES and these skills, in relation to RCR, may be found across all participants.

4.1. Understanding reading comprehension resiliency (RCR) in adolescents with dyslexia

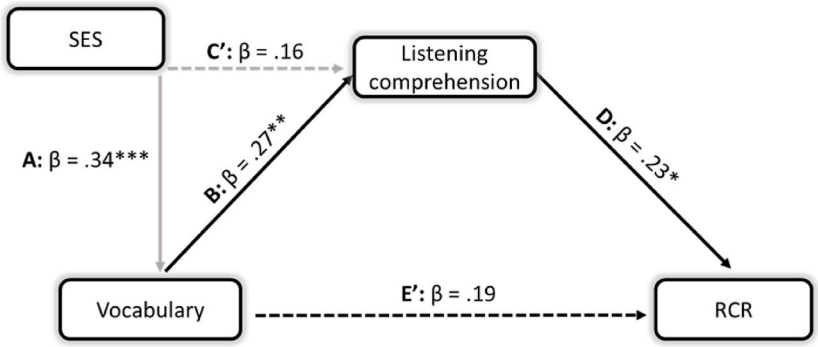
The results of the present study confirmed the presence of RCR, as measured with a continuous index, in adolescents with dyslexia. This indicates a higher reading comprehension level compared to reading fluency. Group comparisons revealed a cognitive profile of individuals with dyslexia characterized by significant impairments in phonological awareness and reading fluency. The dyslexic group did not exhibit, on average, impaired reading comprehension compared to typical readers, supporting the hypothesis that reading comprehension is not a primary deficit in dyslexia (Vellutino et al., 2004). Additionally, listening comprehension and vocabulary scores were not lower in the dyslexic group than in typical readers. This finding aligns with other studies suggesting that observed semantic deficits in dyslexia are not primary

Table 2
Complete correlation matrix with r coefficients and *p*-values.

	1. RCR index	2. Reading Fluency	3. Reading Comprehension	4. Listening Comprehension	5. Vocabulary	6. SocioEconomic Status index
1	–	−0.57 ***	0.57 ***	0.3 **	0.26 *	0.16 ns.
2		–	0.34 **	0.08 ns.	0.25 *	0.07 ns.
3			–	0.41 ***	0.56 ***	0.26 *
4				–	0.33 **	0.28 **
5					–	0.43 ***

Note. RCR: Reading comprehension resiliency, ns: non-significant, *: *p*-value <0.05, **: *p*-value <0.01, ***: *p*-value <0.001. *P*-values are corrected with the False-Discovery Rate (Benjamini & Hochberg, 1995).

a



b

	β	SE	Z & p-value	CI 95%
Indirect effect				
SES on LC SES → Voc →LC	0.09	0.04	2.13*	[0.007; 0.178]
Voc on RCR Voc → LC → RCR	0.06	0.04	1.72 n.s.	[-0.009; 0.134]
SES on RCR SES → Voc → LC → RCR	0.02	0.01	1.55 n.s.	[-0.006; 0.049]
SES → Voc → RCR	0.07	0.04	1.65 n.s.	[-0.012; 0.143]
SES → LC → RCR	0.04	0.03	1.28 n.s.	[-0.019; 0.093]
Total SES on RCR SES → Voc → LC → RCR SES → Voc → RCR SES → LC → RCR	0.12	0.05	2.53*	[0.028; 0.220]

Fig. 3. Path analysis and result of the indirect and total effect. a) representation of the path analysis picturing the relationships between SES Index, listening comprehension (LC), and vocabulary (Voc) with respect to Reading Comprehension Resiliency (RCR) b) Summary of the indirect and total effect (standard coefficient and Standard Error) with test and significance value (Z and p-value) and confidence interval (bias corrected CI 95%).

Table 3
Estimated parameters (β) of the SEM with bootstrapped standard errors (SE; n = 3000) and significance test values (Z and p-value).

Dependent variable	Explaining variable	β	Bootstrapped Standard Error	Z	p
RCR index	Vocabulary	0.19	0.10	1.89	0.058
Listening comprehension	Vocabulary	0.27	0.09	2.74	0.006
RCR index	Listening comprehension	0.23	0.11	2.09	0.036
Vocabulary	SES	0.34	0.09	3.72	<0.0001
Listening comprehension	SES	0.16	0.09	1.61	0.107

Note. RCR: Reading Comprehension Resiliency.

impairments but may result from a poorer reading experience (Cain & Oakhill, 2011). These results collectively reinforce the idea that dyslexia primarily affect phonological processing and reading fluency, rather than comprehension skills.

As proposed by Jackson and Doellinger (2002), the RCR profile may be commonplace in individuals with dyslexia. In our mediational model, the continuous RCR index was associated with listening comprehension which was associated with vocabulary. This key result is in line with studies demonstrating the importance of semantic abilities in determining the dissociation between reading fluency and reading comprehension as in the case of RCR (Binder, Chace, & Manning, 2007; Farris et al., 2021; Jackson & Doellinger, 2002; Welcome et al., 2009). The model, as a continuous measure, may also explain the trend for an inverse profile, where individuals possess stronger reading fluency compared to reading comprehension.

The absence of difference between adolescents with dyslexia and typical readers on the different measures of vocabulary does not support the hypothesis that resilience arises from the strength or size of the lexicon (see Cavalli et al., 2016, for results on university students with dyslexia). Instead, resilience may involve an alternative and more extensive use of semantic abilities to circumvent phonological/decoding impairments, a mechanism previously defined as semantic bootstrapping (Haft, Myers, & Hoeft, 2017; Muter & Snowling, 2009). Although the semantic bootstrapping hypothesis has primarily been used to explain improvements in reading fluency, this mechanism could also partially explain RCR. Conversely, a lack of semantic skills seems to result in a profile where reading fluency is more proficient than reading comprehension, closely resembling the profile of poor comprehenders (Catts, Adlof, & Weismer, 2006). However, none of our participants were diagnosed with reading comprehension deficit, so this

interpretation should be taken with caution.

4.2. The role of socioeconomic status (SES) in reading comprehension development

Lastly, SES was found to have a total indirect effect on RCR index via all the possible indirect effects available in the model. While lower SES may act as a risk factor for children (potentially impeding the development of adequate semantic skills), higher SES may in contrast act as a supporting factor (potentially facilitating the development of adequate semantic skills). These findings are consistent with previous research demonstrating the impact of SES on language development (Beitchman et al., 2008; Bowey, 1995; Fernald et al., 2013; Hart & Risley, 1995; Korat et al., 2007; Walker et al., 1994). Given the importance of RCR in individuals with dyslexia, low SES might be considered an additional risk factor, potentially hindering the development of proficient adult reading comprehension levels in this population. It is also important to note that children from low SES backgrounds, who tend to have lower semantic skills, could be at risk of exhibiting a profile similar to poor comprehenders (Locke, 2002). This highlights the critical and time-sensitive role that the family environment plays in fostering long-term reading ability outcomes. This supports the idea that family-based interventions may be useful but may also take place relatively early in development. For example, Leung, Hernandez, and Suskind (2020) demonstrated the positive effects of early, evidence-based interventions on caregivers' interactions with their children, which can enhance language development. Additionally, evidence-based programs have also been developed for school-aged children, in order to increase semantic knowledge and especially vocabulary depth (Potocki, Chailleux, Gimenes, & Pylouster, 2021).

4.3. Limitations and directions for future research

The main limitations of the present study are its correlational and cross-sectional design as well as its limited sample size. Specifically, the correlational nature of our findings does not make it possible to support causal claims. This limitation is particularly relevant for the mediation models employed in our analysis. While the observed relationships align with our hypothesized framework, alternative models could also fit our findings. Determining the most plausible mediation model ultimately depends on prior empirical evidence, logical reasoning, and theoretical foundations (Fiedler, Harris, & Schott, 2018). Specifically, the model depicted in Fig. 1 is grounded in prior evidence. Nonetheless, further large-sample studies using both longitudinal and interventional designs are needed to formally test whether an increase in semantic abilities increases RCR, in individuals with dyslexia. Our study relies on a merged sample of individuals with and without dyslexia, while it is an established approach to account for the continuous nature of reading skills (Lefèvre, Law, Quémart, Anders, & Cavalli, 2023; Van Der Auwera et al., 2021), individuals with dyslexia are over-represented in our sample compared to the general population, which could pose a potential limitation to generalisability. In addition, SES is a proxy measure for a bundle of mechanisms that may lead to lower language abilities in children, including stress and more limited cognitive stimulations (for a review see Ursache & Noble, 2016). Future studies should focus on the proximal mechanisms that are implied by different SES developmental contexts. The relationship between SES and language development also intersects with other risk factors for dyslexia. For example, children from lower SES backgrounds are more likely to encounter stressors such as inadequate access to educational resources, less stimulating home literacy environments or reduce availability of early identification and intervention services. These factors can further impede language development and reading acquisition (Catts & Petscher, 2022). In addition to the previously mentioned lack of exposure to oral language, stress related mechanisms and its toll on neurocognitive development (Tooley, Bassett, & Mackey, 2021) should be the focus of future study in the field of learning disabilities.

4.4. Conclusion

In the present study, we demonstrated a link between semantic abilities and RCR, along with a relationship between RCR and family SES. The originality of the study also rests on the fact that environmental variables and their effect on semantic variables are rarely studied in the framework of dyslexia. Our study suggests that such environmental variables, especially SES, might explain consequent levels of inter-individual variation in linguistic abilities, and opens opportunities for models with more explanatory power that can assess risk, compensatory, and resiliency relationships.

CRediT authorship contribution statement

Elise Lefèvre: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jeremy M. Law:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Conceptualization. **Jérôme Prado:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis. **Royce Anders:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis. **Eddy Cavalli:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Ethical considerations

All participants and their legal guardian have consented both orally and in writing to this study. Participants and their legal guardians had the right to withdraw their participation at any time.

Data availability

The anonymized dataset is available at the following repository: https://osf.io/fzyeh/?view_only=None.

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Data availability

Data are available on a dedicated osf maintained by the first author.

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