## 1. INTRODUCTION

Education is an essential part of the human capital of all societies (Becker, 2009). The ability to read, write and obtain overall scholastic knowledge in adolescence is particularly important given that school dropout and repetition are frequent at this developmental stage, which can lead to strong downstream effects on individual future accomplishments (Hollenstein & Lougheed, 2013; Valiente et al., 2013). Among important factors that influence youth education are environmental context, such as region and socioeconomic status (SES), as well as individual differences in intelligence, psychopathology and temperament (Deary, Strand, Smith, & Fernandes, 2007; Esch et al., 2014; Heckman & Kautz, 2012; Author 1, Year 1; Melkevik, Nilsen, Evensen, Reneflot, & Mykletun, 2016; Rothbart, 1998; Sirin, 2005).

However, education is not a simple process and cannot be summarized in a single indicator. It encompasses quantitative and qualitative aspects (Barratt, Chawla-Duggan, Lowe, Nikel, & Ukpo, 2006). Quantitative aspects often refer to supply and if people are enrolled in a given educational environment. Qualitative aspects comprehend a broader and complex definition, which includes learning, achievement and skill acquisition. Prior to understanding temperament's association with different educational outcomes, the context of its measurement must be taken into account.

### 1.1. Brazilian educational context

The educational system in Brazil must be understood within its particularities. School enrolment is compulsory (Author 2, year 1) from 4 to 17-year-old subjects since 2009, when constitutional amendment 59 was enacted. From 4 to 5 years old, children must be enrolled in pre-school. From 6 to 14, youths must be enrolled in elementary school and from 15 to 17 they should be enrolled in high school. It is the same basic

curriculum for every student from elementary to high school, and it comprehends portuguese, literature, english, math, sciences (physics, chemistry and biology), geography, history, physical education, art and religion (Brasil, 2018). Locally, schools can add specific lectures and topics (Brasil, 2018). In 2010, the year that the present data was collected, 23.7% of the population was within the age range to be enrolled in schools (IBGE, 2012) and during the last century and early 2000s, Brazil reached nearly 100% of school supply (OECD, 2014). However, the rate of enrolment differs from elementary (97.1%) to high school (84.4%) in urban areas (84% of the population in 2010), with no major differences between gender (IBGE, 2012).

Despite an important decrease in absolute poverty (less than 10% of the population in 2010), Brazil remains as one of the highest levels of inequality in the world (Jens and Jalles, 2014). Education is intimately linked with these indicators as it may possibilitate an increase of income in the labour market. From 2001 to 2011, most of the poverty reduction was linked to investments in education and in this period, enrolment of adolescents on the lowest income quintile more than doubled (Arnold & Jalles, 2014). This change makes Brazil one of the fastest-improving countries in youth abilities regarding math and literacy measured by PISA, despite still remaining one of the lowest levels, comparing with other countries (Gasior, 2013).

In this context, considering improvements made in the last 20 years, Brazil remains with important problems in school attendance and learning (Arnold & Jalles, 2014; Gasior, 2013; IBGE, 2012) and different approaches are needed to foster quantity and quality of education, such as investing in behavioural and emotional traits, in which temperament is included (Heckman & Kautz, 2012).

## 1.2. Temperament

The relationship between temperament and education has been researched since the early 1980s (Keogh, Pullis, & Cadwell, 1982; Martin, Drew, Gaddis, & Moseley, 1988; Martin & Holbrook, 1985). From those years on, educational-related outcomes, such as achievement and attainment, are found to be influenced by temperament, by direct and indirect ways (Al-Hendawi, 2013; Checa & Abundis-Gutierrez, 2017; Checa, Rodríguez-Bailón, & Rueda, 2008; Guerin, Gottfried, Oliver, & Thomas, 1994; Martin et al., 1988; Mullola et al., 2010; Posner & Rothbart, 2007; Rothbart, 1998; Teglasi, Cohn, & Meshbesher, 2004). Temperament can be conceptualized by Rothbart's psychobiological model (Rothbart, 1981) which comprehends biologically-driven individual differences in reactivity and self-regulation of emotion, motivation and attentional processes.

The Rothbart's model is organized in three broad dimensions, which regulate attentional and orienting processes (effortful control, EC), defensive reactions of fear and anger (negative affectivity) and approach reactions towards positive emotions and pleasure (extraversion) (Rothbart, 2007). These higher order dimensions are composed by lower order, which varies between studies and in some, temperament is modelled only by its lower order dimensions. In fact, in its validation study, four factors emerged from the exploratory factor analysis of the Early Adolescent Temperament Questionnaire-Revised (EATQ-R), which were the dimensions mentioned above plus affiliativeness (Ellis & Rothbart, 2001). Using confirmatory factor analysis, studies have tested different model structures, from correlated (Hankin et al., 2017) to second-order (Kim, Brody, & Murry, 2003) and even a three orthogonal bifactor models (Snyder et al., 2015). In a previous study (Author 1, Year 2), we tested nine models of EATQ-R using EC, fear, frustration, shyness and surgency subscales. Among the nine models, we tested the theoretical three-dimensional model (EC, negative affectivity and extraversion) in an

orthogonal and correlated manner, correlated and orthogonal five first-order, second-order as well as bifactor models. The best fit came from a bifactor model in which EC was orthogonal with the other four dimensions, and other models had unacceptable fit. Cultural and other differences might explain differences among studies and despite divergences, some agreement in temperament broader structure and its concept exists among studies, and its impact have been registered.

Dispositional traits could be influenced by programmed biological changes in adolescence (Hollenstein & Lougheed, 2013; Mychasiuk & Metz, 2016; Sisk & Foster, 2004) and this sensible period of life can modify developmental trajectory (Gulley, Hankin, & Young, 2016; Paus, Keshavan, & Giedd, 2008). Educational outcomes may be specially influenced (Heckman, 2008; Posner & Rothbart, 2007). Previous studies address associations in between temperament and later life outcomes, which encompass education and explain achievement beyond the influence of parenting (Checa & Abundis-Gutierrez, 2017). In this sense, each temperament may have a different mechanism of association.

### 1.2.1. Effortful control

Regarding education, EC is the most important and well described temperament (Liew, 2012; Nigg, 2016; Rothbart, 1998). In structure, it is composed by attentional and inhibitory control (Rothbart, 2007), but also by activation (Ellis, 2002; Snyder et al., 2015). This structure reveal that EC is characterized by the ability to focus and shift attention when desired, plan and supress inappropriate responses as well as to perform action when there is a strong tendency to avoid it (Ellis, 2002; Ellis & Rothbart, 2001).

Higher EC predicts better general achievement, reading ability and learning (Blair & Razza, 2007; Checa & Abundis-Gutierrez, 2017; Deater-Deckard, Mullineaux, Petrill,

& Thompson, 2009; Posner & Rothbart, 2007; Snyder et al., 2015; Valiente et al., 2013; Zhou, Main, & Wang, 2010). Besides direct effects, EC can be mediated by school participation, engagement and attendance (Checa, Rodríguez-Bailón, & Rueda, 2008; Liew, 2012; Snyder et al., 2015; Valiente et al., 2008; Valiente, Swanson, & Lemery-Chalfant, 2012). It can also affect behaviours and regulate impulses that will lead to better learning (Duckworth & Allred, 2012; Sánchez-Pérez, Fuentes, Eisenberg, & González-Salinas, 2018). This evidence suggests that higher EC is beneficial to compensate environmental factors and it acts independently of intelligence for achievement and learning.

However, despite evidence on direct and mediated effects, few evidence exists regarding the predicted theory of EC's potential as a moderator of other temperament dimensions in educational outcomes (Rothbart, 2007). Previous evidence did not find moderation between EC and impulsivity (Valiente et al., 2013) and with anger/frustration (Zhou et al., 2010) for school achievement in samples from USA and China respectively. However, EC interacts with negative emotions for other possible mediators of temperament and achievement, such as teacher relationship and academic engagement (Diaz et al., 2017). On top of that, the possibility of negative affect and extraversion to modify the effect of EC is almost neglected, despite being a consequence of the hypothesized interaction of temperament dimensions. More studies are necessary, with larger samples in different settings, to explore the hypothesis of moderation of EC on affective temperament and in which direction it occurs.

### 1.2.2. Fear

As a negative affect related to anticipation of distress, it can motivate youths to avoid problems through attention towards threats and punishment, which can inhibit aggressive behaviour and observation of rules (Posner & Rothbart, 2006). However, fear

is usually combined with frustration (within the frame of negative affectivity) or anxiety, which decreases the evidence regarding the specific association of this temperament with educational outcomes. As a combination, negative affect decreases school achievement in young toddlers (Liu et al., 2018) and school functioning in adolescents (Snyder et al., 2015). In this age, negative affect also mediates parenting style and academic performance, but this effect is not significant if EC is taken into account, which highlights the importance of adjusted models by multiple temperament dimensions (Checa & Abundis-Gutierrez, 2017). At the same time, high negative affect is related to low task avoidance in young children, which is beneficial for learning (Hirvonen et al., 2016). As important as adjusting for multiple dimensions of temperament, it is also to separating fear and frustration, since these are related to different approach behaviours, as the tendency for fear is avoidance and to frustration is approach (Brotman et al., 2017; Watson & Clark, 1984) and it might be an explanation for some positive associations of negative affectivity with school outcomes.

### 1.2.3. Frustration

Frustration (i.e., negative affect associated with interruption of goals) is also part of negative affect and anger is often used synonymously (Rothbart, 1998; Smith & Bridgett, 2018). Frustration can impair emotional understanding which decreases social competence (Verron & Teglasi, 2018), an important factor for education (Heckman, 2008). It is negatively correlated with achievement (Snyder et al., 2015; Zhou et al., 2010) and framed as anger, is an early predictor (mediated by social skills) of academic competence in early adolescence (Dollar, Perry, Calkins, Keane, & Shanahan, 2018). However, it is not related to self-regulation skills (Nozadi, Spinrad, Eisenberg, & Eggum-Wilkens, 2015), and evidence shows no moderation by EC for school achievement (Zhou et al., 2010), lacking evidence for other important school outcomes, such as fail, dropout

and literacy.

### 1.2.4. Shyness

Shyness is characterized by the behavioural inhibition to novelty and challenges, especially social (Rothbart, 2007). It can impair learning of novel words in very young children (Hilton, Twomey, & Westermann, 2019) and in early adolescents, it is associated with lower academic achievement when mediated by peer preferences (Coplan, Liu, Cao, Chen, & Li, 2017), but not directly linked with poor achievement (Hughes & Coplan, 2010). Shyness, as a reactive temperament, interacts with the inhibitory control (component of EC) and for those high in this dimension, it promotes less prosocial behaviour and popularity in school (Sette, Hipson, Zava, Baumgartner, & Coplan, 2018). Due to these characteristics, shyness may have a diffuse and independent deleterious impact on education, which could be enhanced by EC.

### 1.2.5. Surgency

In the model of temperament used in the present study, surgency is defined as the pleasure derived from high intensity or novel activities (Ellis & Rothbart, 2001; Rothbart, 2007). Low surgency associates with a decrease in task avoidance in childhood, which is important to engagement towards learning (Hirvonen et al., 2016). In children, despite no direct association with reading skills, surgency modifies the effect of EC in a way that EC only promotes reading in those with low levels of surgency (Deater-Deckard et al., 2009), which provide evidence for interaction at this age.

On the other hand, surgency and shyness may have motivational aspects that keep the sustained interest of new and stimulant goals which could be positive for education (Posner & Rothbart, 2006) (or negative in the case of shyness), albeit it has never been tested if there is overlap between motivational aspects with EC. This might explain why studies are inconsistent regarding the effect of surgency on education (Checa et al., 2008;

Laidra, Pullmann, & Allik, 2007). Another possible source of inconsistency is the shortage of simultaneously analysis of distinct temperament dimensions, which generally compares EC with a positive or negative emotional trait (Checa et al., 2008; Duckworth & Allred, 2012; Valiente et al., 2012; Zhou et al., 2010). These gaps in the literature point lead to a need to understand how distinct temperament dimensions add and interact among each other to impact different aspects of the educational process.

### 1.3. The present study

One of the goals of research on temperament is to explore how one dimension affects the other (i.e., interactions), especially, the affective reactions and the effort made to control them (Rothbart, 2007; Smith & Bridgett, 2018). In that sense, it is important to understand if and how EC interacts with frustration, fear, shyness and surgency in a broad educational context in order to plan specific scenarios (i.e., how useful it is to promote EC training in adolescents with high levels of frustration to prevent school dropout, which is a growing educational problem in Brazil).

The present study aims to answer two gaps. First, educational success is influenced by several factors, including co-occurring traits such as intelligence (Deary et al., 2007; Roth et al., 2015), psychiatric symptoms (Melkevik et al., 2016) and also by SES (Sirin, 2005). Studies aiming to investigate associations between education and temperament need to take individual differences in co-occurring traits when investigating independent effects. One needs to assess whether temperament adds predictive information about educational outcomes above and beyond the levels predicted by the aforementioned covariates.

Second, research on temperament and education does not use models that take instrument's common variance into account and hence, how temperament dimensions add

and modify the effect of each other regarding multiple educational outcomes remains an open question. This can be explored using bifactor models of temperament, which model temperament dimensions independently from common variance (Davies et al., 2015; Author 1, Year 2), and with interactive analysis, which test whether these dimensions could modify the influence of each other on a given outcome (Rothbart, 1998). The few studies that have tested interactions (or moderation) among temperament dimensions have revealed non-significant results for school achievement (Valiente et al., 2013; Zhou et al., 2010). Previous study showed that interactions between a unidimensional construct of positive attributes of behaviour, psychopathology and intelligence are correlated with educational outcomes distinctively (Author 1, Year 1) and also there is interaction between EC and frustration in order to predict mental health problems (Oldehinkel et al., 2007), although not found in predicting grades (Zhou et al., 2010). These findings encourage approach to education in its multiple aspects, such as school attendance and learning, to answer if, besides specific temperament main effect on distinct educational aspects, youth temperament can be interactive for educational outcomes. In practice, it means to answer if youth can use one temperament dimension to modify the impact on another temperament dimension in educational outcomes.

The present study aims to explore these questions. First, we evaluate the associations between five temperament dimensions from an empirically-derived bifactor model (EC, fear, frustration, shyness and surgency) (Author 1, Year 2) with educational outcomes to proxy school attendance and learning: school suspension, repetition and dropout; academic performance, reading and writing abilities. Our analysis is adjusted for age, sex, socioeconomic status, intelligence and psychopathology. Second, we tested interactions among EC and affective temperament dimensions for associations with educational outcomes. Our first hypothesis is that temperament dimensions are

independently associated with multiple educational outcomes. Specifically, due to previously described findings, we expect positive association of EC in all educational outcomes. We also expect that fear and shyness will associate with better learning measures, and frustration and surgency with higher attendance failure and worse academic performance. Our second hypothesis is that temperament dimensions are not independent of each other, and we hypothesize specifically that the association EC can modify the association of the affective temperament, as previously hypothesized (Oldehinkel et al., 2007; Posner & Rothbart, 2007; Zhang & Ziegler, 2016; Zhou et al., 2010).

## 2. METHODS

### 2.1. Participants

For purpose of this study, we used data from the baseline of a large school-based community study - the High Risk Cohort study for Psychiatric Disorders (Author 2, Year 1). The assembled cohort included screening and assessment phases, as well as sociological, phenotypic, genetic and neuroimaging data. At the beginning of the school year (2010), families were interviewed in 22 schools in Porto Alegre and 36 in São Paulo, two major cities in Brazil and capital of their states. A total of 2,512 subjects, from 6 to 15 years of age, and their caregiver, were invited to participate thus written informed consent was obtained from all participants' parents, which provided verbal assent. Household parent report was collected by lay interviewers and youth assessment (self-reports and tests) was conducted by trained psychologists at school (Author 2, Year 1). The sample is representative of the economic social class in Brazil (A class=0.5%; B class=29.6%; C class=64%; D and E class = 6.0%; A being the richest and E the poorest)

(Kamakura & Mazzon, 2016). The study was submitted and approved by the Ethical Committee of the University of São Paulo.

For this specific report, all 9 to 14-year-old participants (n = 1,540) were included in this data analysis, given the questionnaire was constructed to specifically characterize temperament in this age range. Except for being older, this subsample was identical from the total sample in sex ($\chi^2_{1,2296}$ = 0.806; $p$ = 0.369), socioeconomic status ($t_{2294}$ = -0.810; $p$ = 0.418), intelligence ($t_{2214}$=0.204; $p$ = 0.077) and psychopathology measured by Strengths and Difficulties Questionnaire ($t_{2294}$ = -1.384; $p$ = 0.167). The final sample of 1540 was all attending state-funded schools in the city of Porto Alegre (n = 808) and São Paulo (n = 732).

This study is based on a sample and temperament model published previously (Author 1, Year 2). However, the present objective is to analyse temperament associations with educational outcomes rather than testing the temperament model itself and the temperament profile of psychopathology (Author 1, Year 2), contributing to learning and individual differences understanding rather than psychopathology.


**2.2. Socioeconomic status (SES)**

SES was assessed with a standardized instrument validated in Brazil (ABEP, 2010). It is a composite score, which includes the main caregiver's schooling and the number of items at home (colour TV, radio, VCR/DVD, refrigerator, freezer, washing machine, employed maid, bathroom and automobile). SES was transformed in z-scores for each subject.


**2.3. Intelligence measurement**

For intelligence, we estimated IQ using the vocabulary and block design subtests of the Wechsler Intelligence Scale for Children, 3rd edition – WISC-III (Wechsler, 2002), using the Tellegen and Briggs method (Tellegen & Briggs, 1967) and the Brazilian norms (Nascimento & Figueiredo, 2002). We used studentized residuals, adjusted for age, and represented as z-scores.

## 2.4. Psychopathology

Psychopathology was evaluated as a continuous variable (sum of items), using the Strengths and Difficulties Questionnaire (SDQ) reported by the caregiver (Goodman et al., 2000). SDQ is a 25-item questionnaire which provides five scores of behavioural and emotional symptoms. For the purposes of this study, we included "emotional symptoms", "inattention/hyperactivity" and "conduct problems" to generate a composite score (SDQc) that was already used and validated a previous study (Author 1, Year 1). SDQc (Cronbach's $\alpha = 0.703$) was transformed in z-scores for each subject.

## 2.5. Temperament

Young adolescents' temperament was assessed with the Brazilian-Portuguese version of the revised Early Adolescent Temperament Questionnaire (EATQ-R) (Ellis & Rothbart, 2001; Author 2, Year 1), administered by trained psychologists to the youths. This instrument is suited for 9 to 14-year-old subjects. This questionnaire is a 65-items Likert scale, ranging from 1 (always false) to 5 (always true), containing 12 subscales (4-7 items each). In the present study, EC was modelled using 12 items from activation, attention and inhibition subscales and remaining temperament factors using 4 items each (Author 1, Year 2). The factor structure of EATQ-R was generated by confirmatory factor analysis and the best-fitting solution was a bifactor model with one general factor and

five specific factors, described in detail elsewhere (Author 1, Year 2). Briefly, in this previous study, nine factor models were tested, including original model of three broad dimensions of EC, negative and positive affectivity (Ellis, 2002; Ellis & Rothbart, 2001; Snyder et al., 2015). However, the best model was an empirically-derived bifactor model which captured a general factor and the five residual specific temperament dimensions, namely EC, frustration, fear, shyness and surgency, in which EC is orthogonal with other dimensions and frustration is orthogonal with shyness and surgency. In this model, fear correlates with frustration ($r = -0.192$, $p=0.002$), shyness ($r = 0.628$, $p<0.001$) and surgency ($r = -0.783$, $p<0.001$), and also shyness correlates with surgency ($r = -0.596$, $p<0.001$). Model parameters present good fit to the data (Hu & Bentler, 1999), measured by root mean square error of approximation (RMSEA = 0.050; 90% CI 0.047-0.052), comparative fit index (CFI = 0.909) and Tucker Lewis index (TLI = 0.891). Reliability of each factor was also estimated. Omega ($\omega$) coefficient (Raykov, 2001) was reported previously for each factor (Author 1, Year 2). Cronbach's $\alpha$ was calculated for EC ($\alpha$ = 0.734), fear ($\alpha$ = 0.648), frustration ($\alpha$ = 0.665), shyness ($\alpha$ = 0.733) and surgency ($\alpha$ = 0.455). Besides these indexes, this model has the advantage of capturing specific temperament dimensions in a way that it decreases the bias effects of common variance (i.e., self-evaluation) (Davies et al., 2015; Author 1, Year 2).

### 2.6. School and educational outcomes

School attendance failure consisted of caregiver's report of school suspension, repetition and dropout, each report counting as one negative school event. Each event received a score of 1 point that was summed to compute the school attendance failure composite.

The overall academic performance was measured by the caregiver's report of the Child Behavioural Checklist school items (CBCL-school) (Author 1, Year 1). The items were composed by assessment of Portuguese or literature, history or social studies, English or Spanish, mathematics, biology, sciences, geography, and computer studies performance. Each subject was scored as failing, below average, average, and above average. We performed a CFA of CBCL-school items, presenting a one-factor solution with adequate goodness-of-fit and reliability indexes in our total sample (Author 1, Year 1) and the present sample (RMSEA = 0.077, 90% CI 0.067-0.087; CFI 0.998; TLI 0.998; $\alpha$ = 0.947; $\omega$ = 0.911). The composite CBCL-school (academic performance) scores were derived from saved factor scores from the CFA model.

Reading and writing ability was measured throughout participants' scores on the School Performance Test ("Teste de Desempenho Escolar" - TDE) (Stein, 1998). The TDE is comprised of two tests: the reading decode (recognition of 64 words isolated from context) and writing (isolated 34 words in dictation). Both provided excellent model fit and reliability indices and for these two latent variables: TDE-read (RMSEA = 0.009, 90% CI 0.006-0.011; CFI 0.997; TLI 0.997; $\alpha$ = 0.994; $\omega$ = 0.979) and TDE-write (RMSEA 0.020, 90% CI 0.017-0.022; CFI 0.990; TLI 0.989; $\alpha$ = 0.967; $\omega$ = 0.929). Reading and writing abilities were derived from reading and writing saved factor scores. See statistical analysis section for references about CFA fit and reliability indexes.

### 2.7. Statistical analysis

All CFA used delta parameterization and weighted least square with diagonal weight matrix with standard errors and mean- and variance-adjusted chi-square test statistics (WLSMV) estimators. Model fit parameters were RMSEA, CFI and TLI. Values of RMSEA near or below 0.080 represent acceptable model fit, and values lower than

0.060 represent good-to-excellent model fit (Hu & Bentler, 1999). CFI and TLI values near or above 0.900 represent acceptable model fit, while values higher than 0.950 represent a good-to-excellent model fit. Factor scores for each factor were saved from the best model. All CFA were performed using MPlus 7.4 software (Muthén and Muthén, Los Angeles, California, USA). To assess factor reliability, we used Cronbach's α and the ω coefficients. ω is a model-based reliability estimate, analogous to α coefficient, but appropriate for congeneric tests, which have varying factor loadings (Raykov, 2001).

Multilevel regression models (clustered by school, with random intercept) were used to analyse the associations of temperament factors with attendance failure (Poisson regression), academic performance, reading and writing abilities (linear regression). A model depiction is presented in Figure 1. First, a comparison model including age, sex, SES, IQ and SDQc as predictors was run, for each of the four outcomes, to be the comparison model to test the significance of adding temperament to the model (Winter, 2013). Second, each temperament was included separately to the previous models to examine their main effect (single temperament model). Third, all temperament dimensions were included in the same model (multiple temperament model) and finally, interaction terms for EC with fear, frustration, shyness and surgency were added to analyse the increment of adding interactions into the model (interactive temperament model). Interaction testing resulted in 4 models for each outcome (16 total tests). P-values of each interactive term (4 p-values/outcome) were adjusted using Benjamini-Hochberg method for multiple testing ($p_{BH}$) (Benjamini & Hochberg, 1995; Benjamini & Yekutieli, 2001). The same procedure was applied to each outcome in single temperament and multiple temperament models (5 temperament p-values/outcome).

To further explore the significance of the continuous interactions, we used marginal effects estimation, which represents the effects on predicted levels of an

educational outcome for one temperament standardized unit change when the other temperament dimension is held constant at different values (-2.0 to 2.0 standard deviations).

Marginal (fixed effects) and conditional (fixed and random effects) $R^2$ were reported for each model, as well as likelihood ratio $\chi^2$ test to calculate the significance of adding temperament to the comparison model (which include only covariates) (Winter, 2013). Likelihood ratio test for interactive models were compared with the respective multiple temperament model without interaction term. Data analyses were performed in R (version 3.6.0) using "lme4"(Bates, et al., 2016). Interaction was graphically represented using R packages "interplot" (Solt & Hu, 2016) and "persp3D" (Soetaert, 2016) Marginal effects were explored using STATA version 13 (StataCorp, College Station, TX).

## 3. RESULTS

### 3.1.Sample description

Description of predictors and outcomes for the final youth sample with complete temperament data (n = 1,540) are described in Table 1.  Bivariate correlation analysis among all study variables can be seen in supporting information (Table S1)

### 3.2.Associations between temperament and education

To test our first hypothesis, we investigated the associations between each temperament dimension (single temperament models in Table 2), as well as all temperament dimensions simultaneously (multiple temperament models in Table 2) for each of the four educational outcomes.

In accordance with the main hypothesis, when temperament dimensions were added separately in the regression model (with covariates), EC was associated with all educational outcomes including a lower rate ratio for attendance failure, higher academic performance, reading and writing abilities. Fear was associated with lower rate ratio of attendance failure and with better reading ability, and frustration was associated with higher rate ratio of attendance failure and lower academic performance. Surgency was associated with higher rate ratio for attendance failure and poorer reading and writing abilities. Differently to our hypothesis, shyness was not associated with any educational measurements. All regression results and $R^2$ are described in Table 2. Likelihood ratio test results, comparing models including temperament with models including only covariates are reported in supporting information, table S2).

In regression models including all temperament dimensions (with covariates), only EC remains associated with lower rate ratio for attendance failure (OR = .89, 95% CI [.82, .98], $\chi2(5)$ = 16.00, $p_{BH}$ = .007), higher academic performance ($\beta$ = .16, 95% CI [0.11, 0.21], $\chi2(5)$ = 44.24, $p_{BH}$ < .001), reading ($\beta$=.05, 95% CI [.00, .10], $\chi2(5)$ = 13.46, $p_{BH}$ = .019) and writing abilities ($\beta$ = 0.09, 95% CI [.05, .14], $\chi2(5)$ = 23.53, $p_{BH}$ < .001).

### 3.3.Interactions between temperament dimensions on education

To test our second hypothesis, we investigated interactions between temperament dimensions as previously described. After adjustment for multiple testing, the only significant interaction was of frustration with EC ($\beta$ = -.07, 95% CI [-.14, -.01], $p_{BH}$ = .034) for reading abilities (complete interaction results are described in Table 2). This interaction means that the combination of low frustration and low levels of EC adds when looking into associations of temperament and with reading abilities, despite small

increase in $R^2$ compared with the multiple model without interaction term (Table 2). A graphical example of the interaction of EC and frustration can be seen in Panel A of Figure 2. For comparison, a non-significant interaction is represented in Panel D of the same figure.

Marginal effect analysis revealed that increasing levels of EC were significantly associated with higher reading ability for individuals with frustration less than 1.0 z-score, but not for levels of frustration higher than this level (Table 3). In other words, the strength of the association between EC and reading ability approaches non-significance as a function of increasing levels of frustration. For example, at a frustration level of -1.5 z-score, an increase of one EC standardized unit enhances the linear prediction of reading ability in .30 (95% CI [.16, .43], $p_{BH} < .001$). At a frustration level of 0.5 z-score, the linear prediction of reading ability decreases to .07 (95% CI [.012, .13], $p_{BH} < .05$) for each EC standardized unit increase (representation in Figure 2, Panel B). For purposes of comparison, a non-significant marginal effect of EC is depicted in Panel E of the same figure.

Conversely, marginal effect of increasing levels of frustration was associated with higher reading ability for individuals with EC lower .5 z-score. This shows that association of frustration and reading ability approaches to insignificance as a function of increasing levels of EC (Table 3). As an example, at an EC level of -1.5 z-score, an increase of one frustration standardized unit enhances the linear prediction of reading ability in .26 (95% CI [.12, .40], $p_{BH} < 0.001$). At EC level of .0 z-score, the linear prediction of reading ability drops to .089 (95% CI [.02, .16], $p_{BH} < 0.05$) for the same frustration standardized unit increase (representation in Figure 2, Panel C). For purposes of comparison, a non-significant marginal effect of frustration is depicted in Figure 2, Panel F.

## 4. DISCUSSION

Temperament dimensions predicted educational outcomes independently of possible confounders and co-occurring traits, such as age, sex, SES, intelligence and psychopathology. Specifically, EC, fear and shyness were associated with better outcomes and frustration and surgency with worse outcomes. Multiple models adjusting for co-occurring temperament traits revealed the prominent effects of EC in predicting educational outcomes. Furthermore, frustration modified the associations of EC and reading abilities and vice versa, in a way that the combination of both low levels of EC and low levels of frustration are detrimental when associated with the adolescent's reading abilities.

EC showed to be the most important temperament dimension for different aspects of education, since it is independently associated with less attendance failure and better academic performance, reading and writing abilities, when analysed separately or concomitantly with other temperament dimensions. Other studies also found that EC was associated with math and reading abilities in young children (Blair & Razza, 2007; Checa et al., 2008; Liew et al., 2008; Valiente et al., 2008), and aspects such as attention in childhood have important effects on math and reading performance in late adolescence (Breslau et al., 2010). Moreover, previous studies suggested positive effects of EC on classroom participation, teacher-student relationships, grades and school absence (Checa et al., 2008; Valiente et al., 2008, 2012). Self-regulation in children has also been linked to better social relationships and academic achievement (Checa et al., 2008; Liew, 2012). As long as conscientiousness can be related with EC (Heckman & Kautz, 2012; Rothbart, Ahadi, & Evans, 2000), this personality trait has also been associated with better academic performance in young children and earnings and employment in adulthood

(Heckman & Kautz, 2012; Poropat, 2009). EC also has independent effects on reading and writing abilities, a finding that was demonstrated in very young children regarding literacy (Blair & Razza, 2007).

Frustration and fear dimensions are also related with aspects of education, but usually merged as negative affectivity. Since we studied them separately, different findings emerged for the single temperament regression models. Previous study did not find an association of negative affectivity with academic performance (Checa & Abundis-Gutierrez, 2017), whereas the present results revealed a negative association of frustration and performance, and positive association of fear and reading ability. Frustration, anger and impulsivity in children are associated with lower grades, classroom participation and poor social relationships (Valiente et al., 2008, 2012; Zhou et al., 2010). Personality research shows that high levels of agreeableness, in which frustration can be placed at the lower end of this trait (Goldberg, 1990), are associated with higher or better education (Poropat, 2009). Therefore, it is possible that frustration temperament is related to education by lowering the adolescent's tolerance to adverse events.

It is also expected, yet poorly empirically explored (Posner & Rothbart, 2006), that fear independently associates with lower risk ratio for suspensions, repetitions and dropouts and associates with higher reading ability. This indicates a role of fear to keep the youth on track with the same school environment and oriented to learn, possibly by its aforementioned avoiding mechanisms (Posner & Rothbart, 2006). On the other hand, the tendency to seek novelty (i.e., surgency) was positively associated with suspensions, repetitions, dropouts and negatively associated with reading-writing abilities, which has been previously shown (Duckworth & Allred, 2012). Surgency may have a different role in earlier stages of development, influencing sustained interest and involvement in activities (Posner & Rothbart, 2006; Shiner, 2015). However, our model of temperament

factored out the common variance between EC and surgency and, added to our adolescent sample, it revealed a deleterious role of surgency for education, when analysed separately from other dimensions of temperament.

In partial agreement with our second hypothesis, EC interacted with frustration when associated with reading abilities, but not interacted with other outcomes and with other temperament dimensions. Although frustration is not associated with reading abilities in models testing main effects, interactive models show its dependability on EC in order to be linked with the outcome. Our results reveal that in subjects with low levels of frustration, a marginal increase in EC is associated with better reading abilities (Figure 2B). On the other hand, in subjects with low EC, a marginal increase in frustration is associated with better reading abilities (Figure 2C). This means that in order to EC to be able to promote reading ability, frustration levels must be low, and when EC is low, increasing reading ability is promoted by increasing frustration. Motivational aspects might explain this association.

Frustration is related to approach behaviour, especially in non-rewarding situations, but also impulsivity and distress (Brotman et al., 2017). It is possible that proneness to experience frustration can lead one to be motivated to approach a given task and low levels of this temperament lead adolescents to avoid learning due to lack of motivation, specifically if they have low EC. The motivational aspect of this affective trait can be a positive target to be explored in subjects with lower diligence and tenacity provided by EC, given that the combination of low frustration and EC was detrimentally associated with reading abilities. At the same time, adolescents with high levels of frustration do not benefit of increasing EC for reading ability, possibly due to high levels of distress and impulsivity which can lead to the interruption of the learning task (Valiente et al., 2013; Zhou et al., 2010). Previous study did not find this result (Zhou et al., 2010)

which might be due to sample size and power to detect this interaction, found in the present large sample study. But this difference might be due to other reasons. Besides being from a different culture and ethnicity, temperament model used in this analysis does not share common variance and the interactive dimensions are fully orthogonal, which can partially explain this different report.

In the present study, some regression models benefit from adding temperament, due to significantly increase their explained variance. This means that, at least in the Brazilian educational context, focusing on temperament, especially EC, can be a target for testing causality and further intervention to promote better outcomes. There is good and fair amount of evidence suggesting interventions that aim traits that promote self-regulation and top-down control for the general youth population, such as EC, are broadly beneficial for education and adult life chances (Heckman, 2008; Heckman & Kautz, 2012). But our findings suggest that temperament profile can also help to understand what works for whom. Despite little increase in variance explained by adding interaction term, we could hypothesize that adolescents with low EC and which the interventions were not able to increase it, might benefit from increasing frustration, if the positive motivational aspect of this temperament could be channelled to promote reading skills. In that sense, for those with refractory poor EC and poor reading ability, interventions aiming motivation of frustration can have a positive impact. At the same time, adolescents with high levels of EC need to regulate their levels of frustration in order to enable EC to promote reading skills. In that direction, part of the subjects with low reading ability might not benefit from programs aiming to increase EC, because they already have that in high levels, but they might benefit from frustration/emotional regulation.

Nonetheless, this study must be understood in light of its limitations. First, due to its cross-sectional design and modelling, causal interpretations are not adequate. Second,

reports from a single source might not capture the full temperament phenomena. Further studies should investigate whether results are similar to the combination of different sources of information. Nonetheless, an important strength of our study is that assessments on school outcomes were reported by parents or assessed by standardized tests, which decrease associations due to shared method variance. Third, we only tested two-way interactions and temperament can potentially interact in a more complex way. It might be relevant to mention that before adjustment for multiple testing, interactions of EC and frustration emerged for attendance failure and writing abilities. Due to the exploratory nature of this study, this might be taken into account in further research. Also, it is important to bear in mind that the majority of associations were not interactive. Finally, explained variance of models adding temperament are very low (marginal $R^2$). Nonetheless, models including temperament are generally better, as reported in the likelihood tests, and previous literature also reported low explained variance for early adolescence models on school achievement (Guerin et al., 1994)

## 5. CONCLUSION

This study expands the understanding of temperament association with education through multiple outcome analysis and explores in depth its interactions, using a larger middle-income country sample. EC has an important role in educational outcomes, from school attendance to learning. At the same time, for reading skills, EC does not add if frustration levels are high, but frustration can help if EC is low. This might reinforce options on educational policies, once alternatively of investing in training noncognitive skills, schools could optimally use adolescent's dispositional traits to tailor strategies for better educational outcomes. Future prospective studies using causal designs should be performed in order to further explore this issue.

**REFERENCES**

Author 1 (Year 1)

Author 1 (Year 2)

Author 2 (Year 1)

ABEP. (2010). *Critério de Classificação Econômica Brasil*. Associação Brasiliera de Empresas de Pesquisa. (São Paulo).

Al-Hendawi, M. (2013). Temperament, school adjustment, and academic achievement: Existing research and future directions. *Educational Review*, *65*(2), 177–205. https://doi.org/10.1080/00131911.2011.648371

Arnold, J., & Jalles, J. (2014). *Dividing the Pie in Brazil: Income Distribution, Social Policies and the New Middle Class*. https://doi.org/10.1787/5jzb6w1rt99p-en

Barratt, A., Chawla-Duggan, R., Lowe, J., Nikel, J., & Ukpo, E. (2006). *The concept of quality in education: A review of the "international" literature on the concept of quality in education*. Retrieved from https://researchportal.bath.ac.uk/en/publications/the-concept-of-quality-in-education-a-review-of-the-international

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2016). Linear Mixed-Effects Models using "Eigen" and S4 (Version 1.1-12). Retrieved from https://CRAN.R-project.org/package=lme4

Becker, G. S. (2009). *Education and Training. In: Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*. University of Chicago Press.

Benjamini, Y., & Hochberg, Y. (1995). Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing. *Journal of the Royal Statistical Society. Series B (Methodological)*, *57*(1), 289–300.

Benjamini, Y., & Yekutieli, D. (2001). The control of the false discovery rate in multiple

testing under dependency. *The Annals of Statistics*, *29*(4), 1165–1188. https://doi.org/10.1214/aos/1013699998

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development*, *78*(2), 647–663. https://doi.org/10.1111/j.1467-8624.2007.01019.x

Brasil, M. da E. (2018). *Base Nacional Comum Curricular*. Retrieved from http://basenacionalcomum.mec.gov.br/

Breslau, N., Breslau, J., Peterson, E., Miller, E., Lucia, V. C., Bohnert, K., & Nigg, J. (2010). Change in teachers' ratings of attention problems and subsequent change in academic achievement: A prospective analysis. *Psychological Medicine*, *40*(1), 159–166. https://doi.org/10.1017/S0033291709005960

Brotman, M. A., Kircanski, K., Stringaris, A., Pine, D. S., & Leibenluft, E. (2017). Irritability in Youths: A Translational Model. *American Journal of Psychiatry*, appi.ajp.2016.16070839. https://doi.org/10.1176/appi.ajp.2016.16070839

Checa, P., & Abundis-Gutierrez, A. (2017). Parenting and Temperament Influence on School Success in 9–13 Year Olds. *Frontiers in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.00543

Checa, P., Rodríguez-Bailón, R., & Rueda, M. R. (2008). Neurocognitive and Temperamental Systems of Self-Regulation and Early Adolescents' Social and Academic Outcomes. *Mind, Brain, and Education*, *2*(4), 177–187. https://doi.org/10.1111/j.1751-228X.2008.00052.x

Coplan, R. J., Liu, J., Cao, J., Chen, X., & Li, D. (2017). Shyness and school adjustment in Chinese children: The roles of teachers and peers. *School Psychology Quarterly*, *32*(1), 131–142. https://doi.org/10.1037/spq0000179

Davies, S. E., Connelly, B. S., Ones, D. S., & Birkland, A. S. (2015). The General Factor

of Personality: The "Big One," a self-evaluative trait, or a methodological gnat that won't go away? *Personality and Individual Differences*, *81*, 13–22. https://doi.org/10.1016/j.paid.2015.01.006

Deary, I. J., Strand, S., Smith, P., & Fernandes, C. (2007). Intelligence and educational achievement. *Intelligence*, *35*(1), 13–21. https://doi.org/10.1016/j.intell.2006.02.001

Deater-Deckard, K., Mullineaux, P. Y., Petrill, S. A., & Thompson, L. A. (2009). Effortful Control, Surgency, and reading skills in middle childhood. *Reading and Writing*, *22*(1), 107–116. https://doi.org/10.1007/s11145-007-9111-9

Diaz, A., Eisenberg, N., Valiente, C., VanSchyndel, S., Spinrad, T. L., Berger, R., … Southworth, J. (2017). Relations of positive and negative expressivity and effortful control to kindergarteners' student–teacher relationship, academic engagement, and externalizing problems at school. *Journal of Research in Personality*, *67*, 3–14. https://doi.org/10.1016/j.jrp.2015.11.002

Dollar, J. M., Perry, N. B., Calkins, S. D., Keane, S. P., & Shanahan, L. (2018). Temperamental Anger and Positive Reactivity and the Development of Social Skills: Implications for Academic Competence During Preadolescence. *Early Education and Development*, *29*(5), 747–761. https://doi.org/10.1080/10409289.2017.1409606

Duckworth, A. L., & Allred, K. M. (2012). Temperament in the classroom. In *Handbook of temperament* (pp. 627–644).

Ellis, L. K. (2002). *Individual differences and adolescent psychosocial development*. University of Oregon.

Ellis, L. K., & Rothbart, M. K. (2001). *Revision of the Early Adolescent Temperament Questionnaire*. Presented at the Biennial Meeting of the Society for Research in

Child Development, Minneapolis, Minnesota.

Esch, P., Bocquet, V., Pull, C., Couffignal, S., Lehnert, T., Graas, M., … Ansseau, M. (2014). The downward spiral of mental disorders and educational attainment: A systematic review on early school leaving. *BMC Psychiatry*, *14*(1), 237. https://doi.org/10.1186/s12888-014-0237-4

Gasior, K. (2013). OECD: Education at a Glance 2012: OECD Indicators. *Sociologický Časopis / Czech Sociological Review*, *49*(06), 994–997.

Goldberg, L. R. (1990). An alternative "description of personality": The big-five factor structure. *Journal of Personality and Social Psychology*, *59*(6), 1216–1229.

Goodman, R., Ford, T., Simmons, H., Gatward, R., & Meltzer, H. (2000). Using the Strengths and Difficulties Questionnaire (SDQ) to screen for child psychiatric disorders in a community sample. *The British Journal of Psychiatry: The Journal of Mental Science*, *177*, 534–539.

Guerin, D. W., Gottfried, A. W., Oliver, P. H., & Thomas, C. W. (1994). Temperament and School Functioning during Early Adolescence. *The Journal of Early Adolescence*, *14*(2), 200–225. https://doi.org/10.1177/027243169401400206

Gulley, L. D., Hankin, B. L., & Young, J. F. (2016). Risk for Depression and Anxiety in Youth: The Interaction between Negative Affectivity, Effortful Control, and Stressors. *Journal of Abnormal Child Psychology*, *44*(2), 207–218. https://doi.org/10.1007/s10802-015-9997-7

Hankin, B. L., Davis, E. P., Snyder, H., Young, J. F., Glynn, L. M., & Sandman, C. A. (2017). Temperament factors and dimensional, latent bifactor models of child psychopathology: Transdiagnostic and specific associations in two youth samples. *Psychiatry Research*, *252*, 139–146. https://doi.org/10.1016/j.psychres.2017.02.061

Heckman, J. J. (2008). Schools, Skills, and Synapses. *Economic Inquiry*, *46*(3), 289–324. https://doi.org/10.1111/j.1465-7295.2008.00163.x

Heckman, J. J., & Kautz, T. (2012). Hard evidence on soft skills. *Labour Economics*, *19*(4), 451–464. https://doi.org/10.1016/j.labeco.2012.05.014

Hilton, M., Twomey, K. E., & Westermann, G. (2019). Taking their eye off the ball: How shyness affects children's attention during word learning. *Journal of Experimental Child Psychology*, *183*, 134–145. https://doi.org/10.1016/j.jecp.2019.01.023

Hirvonen, R., Torppa, M., Nurmi, J.-E., Eklund, K., & Ahonen, T. (2016). Early temperament and age at school entry predict task avoidance in elementary school. *Learning and Individual Differences*, *47*, 1–10. https://doi.org/10.1016/j.lindif.2015.12.012

Hoffmann, M. S., Leibenluft, E., Stringaris, A., Laporte, P. P., Pan, P. M., Gadelha, A., … Salum, G. A. (2016). Positive Attributes Buffer the Negative Associations Between Low Intelligence and High Psychopathology With Educational Outcomes. *Journal of the American Academy of Child and Adolescent Psychiatry*, *55*(1), 47–53. https://doi.org/10.1016/j.jaac.2015.10.013

Hoffmann, M. S., Pan, P. M., Manfro, G. G., de Jesus Mari, J., Miguel, E. C., Bressan, R. A., … Salum, G. A. (2018). Cross-Sectional and Longitudinal Associations of Temperament and Mental Disorders in Youth. *Child Psychiatry & Human Development*. https://doi.org/10.1007/s10578-018-0846-0

Hollenstein, T., & Lougheed, J. P. (2013). Beyond storm and stress: Typicality, transactions, timing, and temperament to account for adolescent change. *American Psychologist*, *68*(6), 444–454. https://doi.org/10.1037/a0033586

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation*

*Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Hughes, K., & Coplan, R. J. (2010). Exploring processes linking shyness and academic achievement in childhood. *School Psychology Quarterly*, *25*(4), 213–222. https://doi.org/10.1037/a0022070

IBGE. (2012). *Censo demográfico: 2010: Educação e deslocamento: Resultados da amostra*. Retrieved from https://biblioteca.ibge.gov.br/index.php/biblioteca-catalogo?view=detalhes&id=7545

Kamakura, W., & Mazzon, J. A. (2016). Socioeconomic stratification criteria and classification tools in Brazil. *Revista de Administração de Empresas*, *56*(1), 55–70. https://doi.org/10.1590/S0034-759020160106

Keogh, B. K., Pullis, M. E., & Cadwell, J. (1982). A Short Form of the Teacher Temperament Questionnaire. *Journal of Educational Measurement*, *19*(4), 323–329. https://doi.org/10.1111/j.1745-3984.1982.tb00138.x

Kim, S., Brody, G. H., & Murry, V. M. (2003). Factor Structure of the Early Adolescent Temperament Questionnaire and Measurement Invariance Across Gender. *The Journal of Early Adolescence*, *23*(3), 268–294. https://doi.org/10.1177/0272431603254178

Laidra, K., Pullmann, H., & Allik, J. (2007). Personality and intelligence as predictors of academic achievement: A cross-sectional study from elementary to secondary school. *Personality and Individual Differences*, *42*(3), 441–451. https://doi.org/10.1016/j.paid.2006.08.001

Liew, J. (2012). Effortful Control, Executive Functions, and Education: Bringing Self-Regulatory and Social-Emotional Competencies to the Table. *Child Development Perspectives*, *6*(2), 105–111. https://doi.org/10.1111/j.1750-8606.2011.00196.x

Liew, J., McTigue, E. M., Barrois, L., & Hughes, J. N. (2008). Adaptive and effortful control and academic self-efficacy beliefs on achievement: A longitudinal study of 1st through 3rd graders. *Early Childhood Research Quarterly*, *23*(4), 515–526. https://doi.org/10.1016/j.ecresq.2008.07.003

Liu, R., Blankenship, T. L., Broomell, A. P. R., Garcia-Meza, T., Calkins, S. D., & Bell, M. A. (2018). Executive Function Mediates the Association Between Toddler Negative Affectivity and Early Academic Achievement. *Early Education and Development*, *29*(5), 641–654. https://doi.org/10.1080/10409289.2018.1446880

Martin, R. P., Drew, K. D., Gaddis, L. R., & Moseley, M. (1988). Prediction of elementary school achievement from preschool temperament: Three studies. *School Psychology Review*, *17*(1), 125–137.

Martin, R. P., & Holbrook, J. (1985). Relationship of Temperament Characteristics to the Academic Achievement of First-Grade Children. *Journal of Psychoeducational Assessment*, *3*(2), 131–140. https://doi.org/10.1177/073428298500300204

Melkevik, O., Nilsen, W., Evensen, M., Reneflot, A., & Mykletun, A. (2016). Internalizing Disorders as Risk Factors for Early School Leaving: A Systematic Review. *Adolescent Research Review*, *1*(3), 245–255. https://doi.org/10.1007/s40894-016-0024-1

Mullola, S., Ravaja, N., Lipsanen, J., Hirstiö-Snellman, P., Alatupa, S., & Keltikangas-Järvinen, L. (2010). Teacher-perceived temperament and educational competence as predictors of school grades. *Learning and Individual Differences*, *20*(3), 209–214. https://doi.org/10.1016/j.lindif.2010.01.008

Mychasiuk, R., & Metz, G. A. S. (2016). Epigenetic and gene expression changes in the adolescent brain: What have we learned from animal models? *Neuroscience & Biobehavioral Reviews*. https://doi.org/10.1016/j.neubiorev.2016.07.013

Nascimento, E. do, & Figueiredo, V. L. M. de. (2002). WISC-III and WAIS-III: Alterations in the current american original versions of the adaptations for use in Brazil. *Psicologia: Reflexão e Crítica*, *15*(3), 603–612. https://doi.org/10.1590/S0102-79722002000300014

Nigg, J. T. (2016). Annual Research Review: On the relations among self-regulation, self-control, executive functioning, effortful control, cognitive control, impulsivity, risk-taking, and inhibition for developmental psychopathology. *Journal of Child Psychology and Psychiatry*, n/a-n/a. https://doi.org/10.1111/jcpp.12675

Nozadi, S. S., Spinrad, T. L., Eisenberg, N., & Eggum-Wilkens, N. D. (2015). Associations of anger and fear to later self-regulation and problem behavior symptoms. *Journal of Applied Developmental Psychology*, *38*, 60–69. https://doi.org/10.1016/j.appdev.2015.04.005

OECD. (2014). Chapter 2. Education and training for Brazilian youth. *Investing in Youth: Brazil*, 71–126. https://doi.org/10.1787/9789264208988-6-en

Oldehinkel, A. J., Hartman, C. A., Ferdinand, R. F., Verhulst, F. C., & Ormel, J. (2007). Effortful control as modifier of the association between negative emotionality and adolescents' mental health problems. *Development and Psychopathology*, *19*(2), 523–539. https://doi.org/10.1017/S0954579407070253

Paus, T., Keshavan, M., & Giedd, J. N. (2008). Why do many psychiatric disorders emerge during adolescence? *Nature Reviews Neuroscience*, *9*(12), 947–957. https://doi.org/10.1038/nrn2513

Poropat, A. E. (2009). A meta-analysis of the five-factor model of personality and academic performance. *Psychological Bulletin*, *135*(2), 322–338. https://doi.org/10.1037/a0014996

Posner, M. I., & Rothbart, M. K. (2006). *Educating the Human Brain* (1 edition).

Washington, DC: Amer Psychological Assn.

Posner, M. I., & Rothbart, M. K. (2007). Temperament and Learning. In *Educating the human brain* (pp. 121–146). https://doi.org/10.1037/11519-006

Raykov, T. (2001). Estimation of congeneric scale reliability using covariance structure analysis with nonlinear constraints. *British Journal of Mathematical and Statistical Psychology*, *54*(2), 315–323. https://doi.org/10.1348/000711001159582

Roth, B., Becker, N., Romeyke, S., Schäfer, S., Domnick, F., & Spinath, F. M. (2015). Intelligence and school grades: A meta-analysis. *Intelligence*, *53*, 118–137. https://doi.org/10.1016/j.intell.2015.09.002

Rothbart, M K. (1981). Measurement of temperament in infancy. *Child Development*, 569–578.

Rothbart, M. K., Ahadi, S. A., & Evans, D. E. (2000). Temperament and personality: Origins and outcomes. *Journal of Personality and Social Psychology*, *78*(1), 122–135.

Rothbart, M. K. J. (1998). Temperament, Self-Regulation, and Education. *School Psychology Review*, *27*(4), 479–491.

Rothbart, Mary K. (2007). Temperament, Development, and Personality. *Current Directions in Psychological Science*, *16*(4), 207–212. https://doi.org/10.1111/j.1467-8721.2007.00505.x

Salum, G. A., Gadelha, A., Pan, P. M., Moriyama, T. S., Graeff-Martins, A. S., Tamanaha, A. C., … Rohde, L. A. (2015). High risk cohort study for psychiatric disorders in childhood: Rationale, design, methods and preliminary results. *International Journal of Methods in Psychiatric Research*, *24*(1), 58–73. https://doi.org/10.1002/mpr.1459

Sánchez-Pérez, N., Fuentes, L. J., Eisenberg, N., & González-Salinas, C. (2018). Effortful control is associated with children's school functioning via learning-related behaviors. *Learning and Individual Differences*, *63*, 78–88. https://doi.org/10.1016/j.lindif.2018.02.009

Sette, S., Hipson, W. E., Zava, F., Baumgartner, E., & Coplan, R. J. (2018). Linking Shyness With Social and School Adjustment in Early Childhood: The Moderating Role of Inhibitory Control. *Early Education and Development*, *29*(5), 675–690. https://doi.org/10.1080/10409289.2017.1422230

Shiner, R. L. (2015). The development of temperament and personality traits in childhood and adolescence. In M. Mikulincer, P. R. Shaver, M. L. Cooper, & R. J. Larsen (Eds.), *APA handbook of personality and social psychology, Volume 4: Personality processes and individual differences* (pp. 85–105). Washington, DC, US: American Psychological Association.

Sirin, S. R. (2005). Socioeconomic Status and Academic Achievement: A Meta-Analytic Review of Research. *Review of Educational Research*, *75*(3), 417–453. https://doi.org/10.3102/00346543075003417

Sisk, C. L., & Foster, D. L. (2004). The neural basis of puberty and adolescence. *Nature Neuroscience*, *7*(10), 1040–1047. https://doi.org/10.1038/nn1326

Smith, C. L., & Bridgett, D. J. (2018). Moving Forward in the Study of Temperament and Early Education Outcomes: Mediating and Moderating Factors. *Early Education and Development*, *29*(5), 619–623. https://doi.org/10.1080/10409289.2018.1463836

Snyder, H. R., Gulley, L. D., Bijttebier, P., Hartman, C. A., Oldehinkel, A. J., Mezulis, A., … Hankin, B. L. (2015). Adolescent emotionality and effortful control: Core latent constructs and links to psychopathology and functioning. *Journal of*

*Personality    and    Social    Psychology*,    *109*(6),    1132–1149. https://doi.org/10.1037/pspp0000047

Soetaert, K. (2016). Plot3D: Plotting Multi-Dimensional Data (Version 1.1). Retrieved from https://CRAN.R-project.org/package=plot3D

Solt, F., & Hu, Y. (2016). Plot the Effects of Variables in Interaction Terms (Version 1.9-3). Retrieved from https://CRAN.R-project.org/package=interplot

Stein, L. M. (1998). *TDE Teste de Desempenho Escolar*. São Paulo: Casa do Psicólogo.

Teglasi, H., Cohn, andrea, & Meshbesher, N. (2004). Temperament and Learning Disability.    *Learning    Disability    Quarterly*,    *27*(1),    9–20. https://doi.org/10.2307/1593628

Tellegen, A., & Briggs, P. F. (1967). Old wine in new skins: Grouping Wechsler subtests into new scales. *Journal of Consulting Psychology*, *31*(5), 499–506.

Valiente, C., Eisenberg, N., Spinrad, T. L., Haugen, R. G., Thompson, M. S., & Kupfer, A. (2013). Effortful Control and Impulsivity as Concurrent and Longitudinal Predictors of Academic Achievement. *The Journal of Early Adolescence*, 0272431613477239. https://doi.org/10.1177/0272431613477239

Valiente, C., Lemery-Chalfant, K., Swanson, J., & Reiser, M. (2008). Prediction of children's academic competence from their effortful control, relationships, and classroom participation. *Journal of Educational Psychology*, *100*(1), 67–77. https://doi.org/10.1037/0022-0663.100.1.67

Valiente, C., Swanson, J., & Lemery-Chalfant, K. (2012). Kindergartners' Temperament, Classroom Engagement, and Student–teacher Relationship: Moderation by Effortful    Control.    *Social    Development*,    *21*(3),    558–576. https://doi.org/10.1111/j.1467-9507.2011.00640.x

Verron, H., & Teglasi, H. (2018). Indirect Effects of Temperament on Social Competence

via Emotion Understanding. *Early Education and Development*, *29*(5), 655–674. https://doi.org/10.1080/10409289.2018.1449504

Watson, D., & Clark, L. A. (1984). Negative affectivity: The disposition to experience aversive emotional states. *Psychological Bulletin*, *96*(3), 465–490. https://doi.org/10.1037/0033-2909.96.3.465

Wechsler, D. (2002). *WISC-III: Escala de Inteligência Wechsler para Crianças* (3rd ed.). São Paulo: Casa do Psicólogo.

Winter, B. (2013). Linear models and linear mixed effects models in R with linguistic applications. *ArXiv:1308.5499 [Cs]*. Retrieved from http://arxiv.org/abs/1308.5499

Zhang, J., & Ziegler, M. (2016). How do the big five influence scholastic performance? A big five-narrow traits model or a double mediation model. *Learning and Individual Differences*, *50*, 93–102. https://doi.org/10.1016/j.lindif.2016.07.011

Zhou, Q., Main, A., & Wang, Y. (2010). The relations of temperamental effortful control and anger/frustration to Chinese children's academic achievement and social adjustment: A longitudinal study. *Journal of Educational Psychology*, *102*, 180–196.

## Figure 1: General model depiction

Figure 1 – Basic regression model depiction. Age, sex, SES, IQ and SDQc were used as covariates in all models. Each temperament represented in the were added separately for the single temperament regression models (square boxes) and at the same time for multiple temperament regression models (dashed box), as well as with interaction terms (gray dashed lines), here depicted only for interaction with EC and Frustration. School outcomes were attendance failure, academic performance, reading and writing abilities. EC, effortful control; SES, socioeconomic status; IQ, intelligence quotient; SDQc, Strength and Difficulties Questionnaire composite of emotional, hyperactivity and conduct problems.

# Figure 2: Interaction between effortful control and frustration in reading ability (non-significant interaction depicted for comparison).

Figure 2- Graphical demonstration of significant and non-significant Interactions. Panels A-C represents the interactive relationship between effortful control and frustration on reading ability. Panels D-F represents the independent relationship between effortful control and surgency on reading ability. Panels A and D showed tridimensional plots depicting standardized performance in reading abilities (z-score) according to deciles of effortful control and frustration (A) or a temperament with no interactive association, such as surgency (D). Interactions were probed using marginal effects in two ways. First, average marginal effect of increasing one effortful control z-score on the predicted linear coefficient of reading abilities (y-axis) at different z-scores of frustration (B) and surgency (E) (x-axis). Second, average marginal effect of increasing one frustration (C) and surgency (F) z-score on the predicted linear coefficient of reading abilities (y-axis) at different z-scores of effortful control (x-axis). For purposes of comparison, surgency was used to depict a non-significant marginal effect.