THE ASSOCIATION BETWEEN INTELLIGENCE AND TEMPERAMENT IN CHILDHOOD AND EARLY ADOLESCENCE

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Tiivistelmä – Abstrakt – Abstract

Tavoitteet

Älykkyys ja temperamentti ovat kaksi olennaista käsitettä yksilöidenvälisen psykologisen vaihtelun tutkimuksessa. Näiden kahden vaihtelun alan yhteyttä on kuitenkin tutkittu melko rajallisesti. Lukuunottamatta usein toistettua löydöstä, että parempi toiminnanohjaus, eli itsehillintä, keskittymiskyky ja käyttäytymisen tavoitteenmukaisuus, on yhteydessä suurempaan älykkyyteen, tulokset ovat olleet hyvin vaihtelevia. Tämän tutkimuksen tarkoitus oli selvittää, minkälaiset yhteydet vallitsevat älykkyyden ja temperamentin välillä 8-12 vuoden iässä ja onko temperamentti yhteydessä kognitiiviseen kehitykseen kyseisinä ikävuosina.

Menetelmät

Tutkimus käyttää Glaku-tutkimusprojektin osana koottuja tietoja 468 vanhemman ja lapsen muodostamasta parista. Vanhemmat täyttivät lastensa temperamenttia koskevan kyselylomakkeen 8 ja 12 vuoden iässä ja lasten älykkyyttä arvioitiin samanaikaisesti neljällä WISC-III:n osatestillä, joista kaksi edusti verbaalista ja kaksi ei-verbaalista kyvykkyyttä. Kyselylomakkeen vastauksista laskettiin kussakin iässä kolme temperamentin pääpiirrettä sekä näiden alapiirteet. Verbaalisen ja ei-verbaalisen kognitiivisen kyvykkyyden ja temperamentin pääpiirteiden yhteyttä arvioitiin lineaarisen regressioanalyysin keinoin.

Tulokset ja johtopäätökset

Kuten aiempi tutkimus antaa syytä odottaa, toiminnanohjaus on vahvasti yhteydessä älykkyyteen 8- ja 12-vuotiaana. Lisäksi parempi toiminnanohjaus 8-vuotiaana ennustaa parempaa sanavaraston kehitystä 12-vuotiaaksi. Muista temperamenttipiirteistä ujous on yhteydessä huonompaan suoriutumiseen verbaalisissa testeissä 12-vuotiaana ja taipumus negatiivisiin tunteisiin on yhteydessä parempaan suoriutumiseen sekä verbaalisissa että ei-verbaalisissa testeissä 12-vuotiaana. Viimeisin näistä tuloksista on yllättävä aiemman tutkimuksen valossa.

Avainsanat – Nyckelord – Keywords

Älykkyys, Temperamentti

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Tiivistelmä – Abstrakt – Abstract

Goals

Intelligence and temperament are two essential concepts in the study of interpersonal psychological variation. The connections between these two domains of variation have, however, been the subject of only limited research. With the exception of a well-replicated association between intelligence and effortful control, a trait comprising attention, focus, restraint, and goal-oriented behavior, results have been highly varied. The purpose of this study was to examine the associations between intelligence and temperament at ages 8 to 12 and whether temperament is associated with cognitive development during the years in question.

Methods

This study utilizes data collected as part of the Glaku longitudinal research project, on 468 child-parent pairs. The parents filled in questionnaires concerning their child's temperament at ages 8 and 12, and the children were concurrently administered four subtests of the WISC-III, two of which represented verbal and two nonverbal cognitive ability. At each age, three higher-order temperament traits and their constituent lower-order dimensions were estimated from the questionnaire data. The associations between these intelligence and temperament measures were subjected to a series of linear regression analyses.

Results and Conclusions

As predicted from prior research, effortful control is strongly associated with intelligence at ages 8 and 12. In addition, higher effortful control at age 8 is associated with greater improvement in vocabulary from age 8 to age 12. Of the other temperament traits assessed, shyness is associated with poorer verbal performance at age 12, and a tendency to negative emotionality is associated with better cognitive performance at age 12. The latter result is surprising in the light of prior research.

Avainsanat – Nyckelord – Keywords

Intelligence, Temperament

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TABLE OF CONTENTS

1 INTRODUCTION

Temperament and cognitive ability are core concepts in differential psychology, or the study of individual psychological variation. They have much in common: both are predicated on a view of this variation as primarily a matter of dimensional traits, detectable spectra of continuous variation on which each individual occupies a position; both are considered largely, but not perfectly, stable and detectable from a very early age; both are thought to have a biological basis, but one that is expressed in ways dependent on individual environmental factors; and both are considered to exert considerable influence on an individual's exhibited behavior. Nevertheless, the two are not typically considered as belonging to the same domain, but are much more commonly considered in isolation from one another, even though both have been studied in relation to many of the same practical outcomes, such as school performance (e.g. Duckworth & Seligman, 2012; Laidra, Pullmann, & Allik, 2007; Poropat, 2009, 2014; Richardson, Abraham, & Bond, 2012; Rohde & Thompson, 2007; Valiente, Lemery-Chalfant, & Swanson, 2010; von Stumm & Ackerman, 2013; Weber, Lu, Shi, & Spinath, 2013).

There is, however, reason to believe that temperament and cognitive ability are, if not in direct interaction, at least influenced by a number of factors in common. Fundamental psychological processes, such as attention and arousal, are influential in both. Correspondingly, some of the same brain areas have been implicated in studies that have identified individual variation in temperament and cognitive traits (Posner, Rothbart, Sheese, & Voelker, 2014). Not surprisingly, the relationship between intelligence and temperament has been studied extensively, but most such studies have focused on a particular aspect of temperament in exclusion of others. The present study seeks to estimate the strength of association between two aspects, verbal and nonverbal, of cognitive reasoning and three high-order factors of temperament as defined in the Rothbart framework, reviewed in Rothbart & Bates (2006), in middle childhood and adolescence.

1.1 TEMPERAMENT

Temperament is conceived of as an innate mental feature of an individual, a set of tendencies that strongly influence reaction to and interaction with the environment, detectable throughout life from infancy on(Shiner et al., 2012). Of the numerous theoretical frameworks regarding temperament, the one developed by Mary Rothbart and her associates (Rothbart & Bates, 2006) is among the most widely used in research(Shiner et al., 2012). The temperament assessment tools in use in this study, the CBQ (Rothbart, Ahadi, Hershey, & Fisher, 2001) and EATQ-R (Capaldi & Rothbart, 1992; Ellis & Rothbart, 2001) are designed by Rothbart and her associates on the basis of their theory.

In this framework, temperament is a matter of, firstly, an individual's reactivity to the environment, based on the sensitivity and excitability of behavioral systems, ultimately deriving from their physiological substrate, and, secondly, of self-driven moderation and inhibition of this reactivity (Rothbart, Ahadi, & Evans, 2000). The biological basis of the former is supported by its detectability in earliest infancy in both home and laboratory environments and its demonstrated associations with the functioning of physiological response systems (Rothbart, 2007; Rothbart, Ahadi, et al., 2000). The inclusion of mechanisms that regulate these biologically more fundamental involuntary responses is a central feature of the Rothbart theory (Rothbart, Ahadi, et al., 2000), and served to differentiate it from earlier approaches, most specifically the model used by Thomas in their New York Longitudinal Study (NYLS); Rothbart's model has its origins in a reanalysis of the NYLS data that uncovered an underlying structure different from that put forward by the earlier authors (Rothbart, Ahadi, et al., 2000; Rothbart & Bates, 2006).

In the Rothbart theory, temperament is seen as continuous throughout development from infancy to adulthood, displaying both stability and systematic change (Komsi et al., 2006, 2008). It is expected to undergo change with maturation, through the development of greater capacity for self-control and an expanding scope of emotion and motivation as well as behavior (Rothbart, Derryberry, & Hershey, 2000). In infancy and early childhood, temperament is notably stable(Bornstein et al., 2015), but its expression changes considerably as particular tendencies or traits manifest in different ways at different developmental stages (Komsi et al., 2006, 2008; Pedlow, Sanson, Prior, & Oberklaid, 1993; Roberts & DelVecchio, 2000; Rothbart, Derryberry, et al., 2000), and this pattern continues through middle childhood(Komsi et al., 2006; Pedlow et al., 1993; Pesonen et al., 2008; Rothbart, Derryberry, et al., 2000) and into preadolescence (Guerin & Gottfried, 1994; Roberts & DelVecchio, 2000). Some aspects of temperament are less stable than others (Rothbart, Derryberry, et al., 2000).

Temperament is associated with social competence and maladjustment, with specific facets of temperament predicting different clusters of social functioning outcomes (Sanson, Hemphill, & Smart, 2004). The same is true of mental health: various forms of psychopathology are associated with and evidently etiologically connected to specific variation in specific aspects of temperament (Clark, 2005; De Pauw & Mervielde, 2010).

Temperament, as a theoretical construct, is closely related to, but distinct from, the concept of personality as a combination of traits; childhood temperament predicts personality traits in adulthood to a notable degree (Clark, 2005; De Pauw & Mervielde, 2010; Poropat, 2014; Rothbart, Ahadi, et al., 2000), and the former is often conceived of as preceding and, through environmental modulation, effecting the latter (Farrell, Brook, Dane, Marini, & Volk, 2015; Rothbart, 2007; Rothbart, Ahadi, et al., 2000; Zawadzki & Strelau, 2010). In many cases, operationalizations of personality variation tap underlying variation in temperament with equal validity (Rothbart, Ahadi, et al., 2000).

In view of the Rothbart theory's developmental approach to temperament, the series of temperament assessment tools designed by Rothbart and her associates for use with different age groups include different sets of temperament traits, each tailored for the age group in question. After infancy, these traits (with some exceptions) are associated with three higher-order factors: Negative Affectivity/Negative Emotionality, Extraversion/Surgency, and Effortful Control (Putnam, Gartstein, & Rothbart, 2006; Rothbart, 2007; Rothbart et al., 2001; Rothbart & Bates, 2006). While this higher-order factor structure has recently been challenged on the basis of exploratory factor analysis (Kotelnikova, Olino, Klein, Mackrell, & Hayden, 2016), it has strong theoretical support and is seen as widely applicable in research (Rothbart, 2004; Rothbart & Bates, 2006; Shiner et al., 2012).

Negative Affectivity manifests in infancy in the form of proneness to fear and distress, and as poor soothability(Rothbart, 1986). In later childhood and adolescence, a tendency towards anger and frustration on the one hand, and, on the other, sadness, a tendency to lowered mood and activity level in response to unfavorable experiences, become significant aspects of this trait (Putnam et al., 2006; Rothbart, 2007).

Extraversion or surgency develops out of an infant's positive affectivity (Komsi et al., 2006), which first manifests itself in the child's generalized activity level and proneness to vocal activity (Rothbart, 1986). These aspects are retained, so that high-surgency children and adolescents are more active, impulsive, vocal, and prone to laughter (Putnam et al., 2006; Rothbart, 2007). Surgency is further exhibited in such behaviors as seeking out and deriving pleasure from high-intensity and novel experiences, excitement regarding expected pleasurable activities, and seeking social contact and joint experiences with others (Rothbart, 2007).

Effortful Control only becomes apparent after infancy, developing on a substratum of perceptual responsiveness, attention modulation, and approach tendencies (Komsi et al., 2006; Posner, Rothbart, Sheese, & Voelker, 2012; Posner, Rothbart, & Voelker, 2016; Putnam et al., 2006; Rothbart, 1986). Starting from early childhood, it manifests in top-down control of behavior and attention, as well as a tendency for low-intensity pleasure, as opposed to the high-intensity pleasure aspect of surgency (Rothbart, 2007), but also in a desire for physical acts of affection (Putnam et al., 2006) as well as a tendency to smile and laugh (Komsi et al., 2006).

While the structure of temperament reflected in the set of dimensions detailed above is equally valid for both sexes and males and females display equivalent stability in their temperament over time (Bornstein et al., 2015; Putnam et al., 2006), there are notable differences in the distribution of the traits between the sexes. Else-Quest, Hyde, Goldsmith, and Van Hulle (2006) performed a large meta-analysis on studies of temperament to elucidate sex differences in temperament traits in children, estimating differences both in means and variances. They report that effortful control shows a large sex difference in favor of girls, while boys exhibit somewhat higher average surgency; the sexes do not appear to differ in variability in most traits, but surgency and its subtrait shyness show considerably higher variance in boys(Else-Quest et al., 2006).

1.2 COGNITIVE ABILITY IN CHILDHOOD AND EARLY ADOLESCENCE

The central finding of psychometrics, the field of measuring and comparing human cognitive traits, is general intelligence: performance on all cognitively demanding tasks is based largely on the same trait (Spearman, 1904). This trait is commonly referred to as *g*, short for *general factor*, due to its being evident in a statistical analysis of any set of different cognitive tasks: although seemingly unrelated to one another, performance in any one is nevertheless correlated in a positive direction with performance in all others, and one common factor explains a large part of this covariance. Thus the results of very different tasks (whether items from purpose-built IQ tests or other tasks that make notable cognitive demands) can be used as indicators of the same general intelligence. As this general factor explains a large portion of all the interpersonal variation that is attached to the everyday concept of intelligence, it is justified and common to simply refer to it as intelligence.

Intelligence is highly predictive of academic achievement (Gagné & St Père, 2002; Karbach, Gottschling, Spengler, Hegewald, & Spinath, 2013; Kuncel N.R., 2001; Neisser et al., 1996; Rohde & Thompson, 2007; Spinath, Spinath, Harlaar, & Plomin, 2006; Weber et al., 2013), and academic tests can indeed be used to extract a *g* factor that is comparable but not identical with that derived from purpose-built IQ tests (Frey & Detterman, 2004; Rindermann, 2007). For this reason, measures of academic achievement and cognitive ability are often collated. The association between intelligence and school performance, however, is not overwhelmingly strong: large meta-analyses report correlation coefficients of roughly 0.2 (Poropat, 2009; Richardson et al., 2012). Considering the weakness of this relationship, and the independent effects of temperament and personality traits on school performance (Poropat, 2014; Richardson et al., 2012), the use of school performance as a proxy for intelligence does not provide a strong basis for drawing conclusions on intelligence itself in relation with temperament.

The lower-order structure of intelligence, in comparison with the overwhelming importance of *g*, is a more contested matter. A common standard of distinguishing verbal from nonverbal intelligence, perpetuated by the widely used *Wechsler Intelligence Scales for Children* series of tests has been challenged as unfounded, and numerous revisions have been suggested on the basis of, one the one hand, theory, and on the other, exploratory factor analyses (Keith, Fine, Taub, Reynolds, & Kranzler, 2006; Keith & Witta, 1997; Watkins, 2006). Nevertheless, a convention of separating from one another a verbal and nonverbal component of general intelligence exists. One reason for this is the persistent finding of sex differences in the two components: girls and women consistently score slightly higher than boys and men on tests of verbal intelligence (Hyde & Linn, 1988), while the opposite is true for tests that depend on spatial visualization and reasoning (Lynn & Irwing, 2004; Voyer et al., 1995).

Intelligence is a relatively stable trait throughout an individual's lifespan: even though cognitive abilities change due to maturation, experience, and aging, interpersonal differences, once corrected for age, tend to remain the same in both direction and magnitude. Deary et al. have analyzed the results of cognitive tests administered to the same Scottish cohort at ages 11 and 77 (Deary, Whalley, Lemmon, Crawford, & Starr, 2000). They find a correlation coefficient of 0.77 between the two tests. In the same article, they list a number of estimates of stability based on other data, all well in line with their own: ranging from 0.41 to 0.94, with lower values slightly more common in studies in which the initial test was administered before adolescence and the follow-up test in adulthood. In an earlier study focusing on the stability of cognitive ability before adulthood, Magnusson & Backteman (1978) reported a correlation coefficient of .84 for general intelligence tested at ages 10 and 13, and referenced a number of still earlier studies, all of comparable design, with initial testing ages ranging from 7 to 14 and follow-up intervals of 3-8 years, in which correlation coefficients ranging from 0.70 to 0.86 were found. Some of the same studies are also referenced by Schuerger & Witt (1989) in a large review that finds test-retest reliability to increase considerably (from .70 at age 3 to .86 at 12 years and .91 at 15 years) from early childhood to adolescence, and more slowly but monotonously throughout adulthood, when variation in test-retest intervals between different studies is taken into account.

Considering these summaries of data in aggregate, it is clear that cognitive ability is a highly stable trait both in childhood and in maturity, but not so stable that a test result at any given age can be considered representative of ability at a different age without taking into consideration the possibility of significant change in the intervening years. Some degree of the deficit in stability must, of course, be attributed to the less-than-perfect basic reliability of the instruments used.

Intelligence is a highly heritable trait, with estimates of narrow-definition heritability ranging typically from 0.5 to 0.8 (Visscher, Hill, & Wray, 2008). Heritability estimates tend to increase with age, plateauing after adolescence as a source of considerable variance in childhood, the shared family environment, is gradually reduced in influence (Gottfredson, 2004).

The high statistical unity, stability and heritability of intelligence do not imply that it reflects any one specific biological trait. Numerous anatomical and physiological factors seem to be connected to intelligence, but none of them have a very high explanatory power regarding *g* variation. Of these, the relationship between intelligence and brain size has been studied most extensively. Mcdaniel (2005) estimates on the basis of a broad meta-analysis that the correlation coefficient between the two is 0.33 in the entire population (both sexes and all ages), 0.37 in girls and 0.22 in boys. He provides no attempt at interpretation for such a large disparity. The relationships between various other attributes of the brain and intelligence have been studied, and in numerous cases, a significant covariation has been found: Jung have demonstrated a connection between intelligence and grey matter in the frontal and temporal lobes, while Chiang et al. (2009) have done the same in connection with white matter integrity, whereas van den Heuvel, Stam, Kahn, & Hulshoff Pol (2009) have shown intelligence to be related to the mean path length in the network formed by neurons, this being a parameter that represents the general density of connections in a network. The relationship between intelligence and neural activation level has been found to be somewhat complicated (Neubauer & Fink, 2009): the brains of more intelligent individuals expend less metabolic energy when engaged in a relatively easy task, but are *more* metabolically active when the task is a demanding one.

1.3 ASSOCIATION BETWEEN TEMPERAMENT AND INTELLIGENCE

Temperament and intelligence are not independent of one another; rather, a constellation of mutually associated concepts connects them to each other. These concepts are not to be seen as unambiguous elements of intelligence or of temperament, but are associated with both, in the sense of statistical association, and conceptually. The question of whether variation in intelligence is connected to temperament variation is a large one, and has been studied under a wide variety of theoretical frameworks and assessment procedures. Almost all efforts in the field have inspected one or at most a few temperament traits and related it to some measure of cognitive ability. Petrill & Thompson (1993) took a different approach, extracting a single general factor of temperament from a sample of 326 twins' Colorado Childhood Temperament Index (Rowe & Plomin, 1977) responses, and relating this to intelligence. They reported a correlation coefficient of 0.14 between the two general factors, a modest but still notable effect. This result, of course, permits no straightforward interpretation in real terms, as the general factor of temperament is a statistical construct that is not straightforwardly to be considered an indicator of any particular characteristic of a person. However, this general factor should, to some degree, be comparable to the general factor of personality, an analysis of which reveals a general prosocial tendency (Loehlin & Martin, 2011; Rushton, Bons, & Hur, 2008).

1.3.1 SURGENCY/EXTRAVERSION

One of the aforementioned traits that relate to both temperament and cognition is arousal, which corresponds quite closely to the activity level aspect of surgency in Rothbart's temperament framework (Rothbart, 2007), and has also been found to have predictive value for intelligence (Luciano, Leisser, Wright, & Martin, 2004; Robinson, 1997). Another trait believed to be quite a fundamental characteristic of an individual, reaction time, is connected both to intelligence (Deary, 2010; Deary, Penke, & Johnson, 2010; Stough et al., 1996) and to temperament (Derryberry, 1987; Stough et al., 1996); in Rothbart's system, the role of reaction time in temperament would, also, fall under the surgency trait. In light of these associations, it is not surprising that multiple studies have found a positive correlation between cognitive ability and one measure of extraversion or surgency or another.

Extraversion itself has been studied in relation to cognitive ability, conceptualized and operationalized in different ways and emphasizing different aspects of the trait. Valiente, Lemery-Chalfant, and Swanson (2010) studied a sample of kindergarten students (average age 5.6 years) and reported a correlation coefficient of -0.18 between verbal intelligence and teacher-reported shyness, and a slightly more modest (and nonsignificant) correlation between the former and parent-reported shyness (the two measures of shyness displayed only a moderate connection between themselves). Mobility, a motoric-affective aspect of extraversion particularly apparent in approach behavior, has been found to correlate positively with IQ in children (Miklewska, Kaczmarek, & Strelau, 2006); the same study also uncovered a weaker link between a composite of stimulation processing traits and IQ, but only in one age group of multiple studied ones. Sensation seeking, a close match for Rothbart's high-intensity pleasure scale under a narrow definition but often expanded to a broader meaning, has been reported to correlate with abstract reasoning at a coefficient of 0.21 in adolescents (Colom, Escorial, Shih, & Privado, 2007), while Ripa, Hansen, Mortensen, Sanders, and Reinisch (2001) reported a correlation coefficient of 0.23 between IQ and sensation seeking, with a slightly stronger effect size for verbal than for nonverbal ability.

Some other studies have inspected characteristics falling under the concept of extraversion in connection with language ability specifically. Karrass and Braungart-Rieker (2003) studied the association between language development and temperament in infants and found that a tendency to smiling and laughter was correlated at a coefficient of 0.34 with language development at age 12 months. Slomkowski, Nelson, Dunn, and Plomin (1992) found that a composite measure of extraversion and positive affect assessed at age 2 predicted later verbal performance and intelligence at age 7, with correlation coefficients of 0.14 and 0.16 between affect-extraversion and the WISC-R comprehension and vocabulary subscales, respectively.

In adults, extraversion as conceived of in the context of personality rather than temperament, has been inspected in connection with IQ somewhat extensively, with a wide variety of effect sizes reported in both directions. Wolf (2004) performed a meta-analysis collating studies that together featured more than 10 different personality assessment methods, in combination with several different tests of cognitive ability. He arrived at an estimated population correlation coefficient of 0.05 in the total data: a statistically highly significant effect, but one of relatively modest effect size. A nonlinear relationship between the two traits has also been proposed, and received some support: Stough, Brebner, Nettlebeck, Cooper, & et al. (1996) found that young adults in the middle tertile for extraversion exhibit the best cognitive performance and suggested that this reflects an optimal level of arousal for intellectual performance, neither too low, as exhibited by introverts, nor too high, as in extraverts. This result has, however, been challenged by later research that found an *inverse* relationship between arousal and intelligence, holding for introverts compared with ambiverts (Luciano et al., 2004).

1.3.2 EFFORTFUL CONTROL

Effortful control has also been found to be associated with cognitive performance, although, again, the results across the field are far from invariable. Mousavi et al. (2015) conducted a study on a sample of 452 twins, age 15, and found a correlation coefficient of 0.23 between full-scale IQ as measured using the WISC-IV, and persistence, a temperament dimension reflecting capacity for goal-oriented behavior in the face of discomfort and adversity. A correlation coefficient of 0.41 was reported by Martin and Holbrook (1985) in a sample of 104 first-graders (mean age 7.0 years) for IQ and persistence, with a coefficient of -0.29 between IQ and distractibility, another aspect of effortful control.

There are indications that the relationship between intelligence and effortful control holds over a considerable interval between assessments, with intelligence in toddlers predicting their inhibitory control and task-orientation in middle childhood (Olson, Bates, & Bayles, 1990).

The effect of effortful control appears to hold for both verbal and nonverbal cognitive performance: Valiente, Lemery-Chalfant, and Swanson (2010) found a correlation coefficient of 0.18 in kindergartners between verbal intelligence and a composite measure of effortful control combining parent and teacher reports, while Dobbs, Doctoroff, Fisher, and Arnold (2006) studied mathematical skills in preschoolers in connection with a number of socio-emotional variables, including self-control and attention problems, finding correlation coefficients of 0.33 and -0.45, respectively.

1.3.3 NEGATIVE AFFECTIVITY/EMOTIONALITY

The relationship between affectivity and cognition has been studied extensively, but no association has been found conclusively to hold across the range of different conditions and measures used. The relationship between negative emotionality and intelligence appears to be confounded to some degree by effortful control. Effortful control is negatively associated with negative affectivity, likely in part due to the former representing inhibition of the expression of the latter, and many of the subscales of temperament assessment questionnaires load on both factors, in opposite directions (Komsi et al., 2006; Kotelnikova et al., 2016; Rothbart et al., 2001). Because of this, teasing out the contributions of different temperament traits to IQ is not straightforward.

Some researchers have seen fit to combine the two temperament traits in order to grade or classify subjects on a composite measure of high negative emotionality and low control (or vice versa). Lawson and Ruff (2004) did so, finding a 0.9 standard deviation difference in IQ between children who were both more negative and less attentive than average, and other children (the two variables were negatively associated, but no correlation coefficient is reported). Miklewska, Kaczmarek, and Strelau (2006) found a correlation of 0.25 between performance on Raven's Progressive Matrices and a composite temperamental score representing low emotionality and high control. They found no influence on either of two IQ measures in adolescents and adults for either emotionality or low control, however. Lawson and Ruff (2004) found a correlation of -0.29 between negative emotionality assessed at 1 and 2 years of age and IQ measured at age 3, but a closer examination showed that the association held only for boys.

One aspect of negative emotionality, anxiety, has been studied extensively in connection with working memory, another trait that is not precisely a matter of general cognitive ability (although many IQ tests do include working memory tasks), but is very closely connected with it; in fact, it has even been suggested that working memory is nearly equivalent to *g* (Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004). Anxious children perform more poorly under conditions of high working memory load (Ng & Lee, 2010, 2015; Visu-Petra, Cheie, Benga, & Packiam Alloway, 2011; Visu-Petra, Miclea, Cheie, & Benga, 2009). This effect is stronger on tasks demanding verbal processing than visual ones (Visu-Petra et al., 2011; Visu-Petra, Cheie, & Miu, 2013).

Correlations between measures of cognitive ability and temperament traits are not necessarily found in the expected direction, of positive social valence coinciding with greater ability: Maziade, M.M., Cote, R., Boutin, P., Bernier, H., & Thivierge (1987) found a higher average IQ among 4-year-olds with a temperament profile labeled as "difficult" than in "easy" or intermediate ones, reflecting low control and high emotionality; this result has, however, not found support in a larger sample (Chong et al., 2016). Similarly, Karrass and Braungart-Rieker (2004) found that greater distress to novelty in infancy predicted a higher IQ at age 3, although the relationship held only for insecurely attached infants.

1.4 RESEARCH QUESTIONS

The present study seeks to answer the following questions:

1) To what extent is each of Rothbart's three higher-order temperament factors associated with verbal and nonverbal cognitive performance at 8 to 12 years of age?
2) Are the three higher-order temperament factors associated with change in cognitive performance from age 8 to age 12?

Based on prior research, it is hypothesized that both cognitive ability measures are positively correlated with estimates of extraversion/surgency and effortful control, but negatively correlated with negative emotionality. No hypothesis is proposed concerning the predictive value of temperament for cognitive development.

2 METHODS

2.1 PARTICIPANTS

Table 1: Sample Characteristics

	T1	T2
	N (%) or Mean (SD)	N (%) or Mean (SD)
N	301	372
Boys	145 (48%)	172 (46%)
Finnish as 1st language	NA	356 (96%)
Parent(s) with higher education	156 (52%)	239 (64%)
Mother's liquorice consumption		
<250 mg/week	75 (25%)	93 (25%)
250-500 mg/week	43 (14%)	51 (14%)
>500 mg/week	23 (8%)	38 (10%)
NA	160 (53%)	190 (51%)
Child's age at assessment	8.14 (0.32)	12.30 (0.54)

This study utilizes 8- and 12-year follow-up data collected as part of the Glaku community cohort, consisting initially of 1049 children and their mothers, born between March and November, 1998, in Helsinki, Finland. From this initial cohort, 500 mothers and their children were randomly invited to participate in the 8-year-follow-up (referred to from here on as Time 1 or T1), whereas all the initial respondents were invited to the 12-year follow-up (referred to as Time 2 or T2). At T1, 301 mother-child dyads (60% of those invited, or 29% of the initial sample, 46% of the children male) participated in both the temperament and cognitive assessments, while at T2, 372 did so (35% of the initial sample, all of whom were invited, 48% male). 205 mother-child dyads participated in both temperament and cognitive assessment in both follow-ups (68% of T1 and 55% of T2 participants, 46% male). The full sample for this study, including those who participated in at least some of the assessments at either follow-up or both, consists of 468 mother-child dyads (45% of the initial respondents, 47% male). The characteristics of the sample are shown in Table 1.

Neither the T1 participants nor the T2 participants differed from the original cohort sample in maternal age, maternal alcohol consumption during pregnancy, body length at birth, birth weight, or duration of pregnancy ($p > 0.11$ in all cases). In both follow-up samples, mothers had reported a higher mean licorice consumption during pregnancy than was found in the original cohort sample ($p < 0.001$ in both cases). In addition, a higher percentage of T2 participants' parents reported having undergone university-level education ($p = 0.01$), and maternal stress during pregnancy was reported to be lower than in the rest of the original cohort sample ($p = 0.02$).

The longitudinal sample (those who participated in both follow-ups) was found to differ in parental education from the rest of the T1 sample, the parents of the longitudinal sample having attained university-level education at a higher rate ($p < 0.01$). No difference was found in maternal age, maternal alcohol consumption, maternal licorice consumption, maternal stress, body length at birth, birth weight, or duration of pregnancy ($p > 0.09$ in all cases).

2.2 TEMPERAMENT ASSESSMENT

At T1, the mothers filled in the Finnish translation of the Children's Behavior Questionnaire (CBQ) standard form (Rothbart et al., 2001), which consists of 195 items, evaluated on a 7-step Likert-type scale, reflecting the relative frequency of specific child behaviors in response to particular situations, observed by the parent over the course of preceding weeks. At T2, the Early Adolescent Temperament Questionnaire (EATQ-R) parent-report form (Capaldi & Rothbart, 1992; Ellis & Rothbart, 2001) was used. It is similar to the CBQ, but the number of items is only 62, and the response scale has only 5 steps.

The items of the CBQ are grouped under 13 dimensions, which fall under three higher-order factors. The EATQ-R items represent 8 dimensions. In both questionnaires, the lower-order dimensions fall under three higher-order factors. The higher-order factors for both CBQ and EATQ-R and their respective subscales are as follows:

Extraversion: Represented in the CBQ (Rothbart et al., 2001) by the following subscales: activity level, high-intensity pleasure, impulsivity, positive anticipation, smiling and laughter, and shyness (inverted). Represented in the EATQ-R (Ellis & Rothbart, 2001) by surgency, shyness (inverted), and fear (inverted).

Effortful Control: Represented in the CBQ (Rothbart et al., 2001) by the following subscales: attentional focusing, inhibitory control, low-intensity pleasure, and perceptual sensitivity. Represented in the EATQ-R (Ellis & Rothbart, 2001) by activation control, attention, and inhibitory control.

Negative Affectivity: Represented in the CBQ (Rothbart et al., 2001) by the following subscales: anger/frustration, discomfort, fear, and sadness. Represented in the EATQ-R (Ellis & Rothbart, 2001) by aggression, frustration, and depressive mood.

The three higher-order temperament factors were computed separately at T1 and T2. Each of the resulting six scores was converted into a z-score in respect to the observed sample distribution. The correlation coefficients for each pair of estimates of the same trait at different times, equivalent to a measure of test-retest stability, were 0.45 for Extraversion, 0.58 for Effortful Control, and 0.54 for Negative Affectivity.

2.3 COGNITIVE TESTING

In both follow-ups, children were administered selected subtests from the Finnish translation of the Wechsler Intelligence Scales for Children, 3rd Edition (WISC-III). At T1, the participants undertook the following subtests: Similarities, Vocabulary, Block Design, and Coding; at T2, the subtests administered were the same, with the exception of Picture Arrangement replacing Coding.

The raw scores were converted to z-scores based on the observed distribution. At each follow-up, the standardized scores of Similarities and Vocabulary were summed to produce an index of verbal IQ, and the standardized scores of the two other subtests were likewise summed, producing an index of nonverbal IQ.

For the analysis of cognitive development, the raw scores attained in the Similarities, Vocabulary, and Block Design subtests at T1 and T2 were adjusted for the confounding effect of exact age at the time of assessment, and the difference between the adjusted scores calculated.

The correlation coefficient for the pair of measures of verbal IQ was 0.65; that for nonverbal IQ was 0.56. These coefficients serve as estimates of stability, and are slightly lower than those reported for the stability of cognitive performance over comparable times at the same age (Magnusson & Backteman, 1978; Schuerger & Witt, 1989). This deficit is likely due to the inherently limited reliability of the measures used, as these are calculated from only two WISC-III subtests each, rather than aggregated from the full test.

2.4 STATISTICAL ANALYSES

First, a multiple linear regression analysis was conducted for verbal and nonverbal IQ at T1 and T2 separately, using the concurrently assessed temperament traits as independent variables. The analyses were adjusted for the child's sex and age at assessment. Additionally, the mother's licorice consumption during pregnancy, which has been found to adversely affect cognitive development (Räikkönen et al., 2009, 2017) was adjusted for, after performing a log transformation on the mother's mean weekly glycyrrhizin consumption estimate.

Second, the raw score changes in the three twice-administered WISC-III subtests were subjected to a multiple linear regression analysis, with the temperament traits estimated at T1 as independent, and the change from T1 to T2 in cognitive scores as the dependent variable. As above, the analyses were adjusted for sex and maternal licorice consumption. Age was not corrected for by entering it as a general independent variable at this stage, as the raw scores were adjusted separately for the subject's age at each respective follow-up, and the difference calculated from these adjusted scores.

In the case of both analyses detailed above, an alternative analysis was performed, selecting as dependent variables all those for which one or more statistically significant effects ($p < 0.05$) were found, and with the higher-order temperament factors replaced as predictor variables by their constituent subscales. Those higher-order factors not found to exert a significant effect were removed from among the predictors for these secondary analyses.

3 RESULTS

3.1 ASSOCIATIONS BETWEEN TEMPERAMENT AND COGNITIVE PERFORMANCE AT AGES 8 AND 12

The results of the first analysis are shown in Table 2. As predicted, effortful control was found to be positively associated with both verbal and nonverbal IQ at both ages. Contrary to expectations, higher negative affectivity was associated with higher scores on both IQ measures at T2 (only). For extraversion/surgency, a significant association was found only for verbal IQ at T2, in the positive direction. For each statistically significant

Table 2: The effects of temperament traits on cognitive ability at T1 and T2

	T1						T2					
	Verbal IQ			Nonverbal IQ			Verbal IQ			Nonverbal IQ		
	Beta	95% CI	p	Beta	95% CI	p	Beta	95% CI	p	Beta	95% CI	p
Effortful Control	0.32	(0.08, 0.56)	0.01	0.29	(0.10, 0.47)	0.002	0.42	(0.20, 0.64)	<0.001	0.34	(0.14, 0.54)	0.001
Extraversion/Surgency	0.18	(-0.05, 0.40)	0.13	-0.12	(-0.29, 0.06)	0.20	0.25	(0.06, 0.43)	0.01	0.01	(-0.17, 0.18)	0.95
Negative Affectivity	0.07	(-0.16, 0.29)	0.54	0.17	(-0.01, 0.36)	0.06	0.39	(0.17, 0.61)	0.001	0.25	(0.05, 0.45)	0.02

All traits expressed as z-scores adjusted for sex, age, and mother's licorice consumption during pregnancy

association found, a further regression analysis was performed with the inclusion of an interaction variable between sex and the temperament factor in question. No such interaction effect was found to reach $p < 0.05$.

In order to elucidate the nature of the associations discovered in the first analysis, a further analysis was conducted. The same method was applied, but the higher-order

Table 3: The effects of selected temperament subscales on cognitive ability at T1 and T2

	T1					
	Verbal IQ			Nonverbal IQ		
	Beta	95% CI	p	Beta	95% CI	p
Effortful Control subscales						
Attentional focusing	0.09	(-0.21, 0.39)	0.56	0.35	(0.12, 0.58)	0.003
Inhibitory control	0.03	(-0.27, 0.34)	0.83	0.02	(-0.22, 0.27)	0.85
Low-intensity pleasure	0.20	(-0.08, 0.49)	0.16	-0.06	(-0.29, 0.16)	0.59
Perceptual sensitivity	-0.05	(-0.31, 0.20)	0.68	-0.04	(-0.16, 0.24)	0.67
	T2					
	Verbal IQ			Nonverbal IQ		
	Beta	95% CI	P	Beta	95% CI	p
Effortful Control subscales						
Activation control	0.03	(-0.21, 0.27)	0.81	0.13	(-0.09, 0.35)	0.24
Attention	0.26	(0.02, 0.50)	0.04	0.25	(0.04, 0.46)	0.02
Inhibitory control	0.21	(-0.05, 0.47)	0.11	-0.01	(-0.23, 0.22)	0.95
Extraversion/Surgency subscales						
Fear	-0.06	(-0.26, 0.15)	0.59			
Shyness	-0.26	(-0.46, -0.06)	0.01			
Surgency	-0.01	(-0.22, 0.20)	0.93			
Negative Affectivity subscales						
Aggression	0.16	(-0.11, 0.43)	0.23	-0.11	(-0.35, 0.13)	0.36
Frustration	0.18	(-0.07, 0.43)	0.16	0.23	(-0.00, 0.45)	0.05
Depressive Mood	0.11	(-0.13, 0.34)	0.36	0.14	(-0.06, 0.33)	0.17

Cognitive traits and temperament subscales expressed as z-scores, Sex: 0 = girl, 1 = boy; adjusted for sex, age, and mother's licorice consumption during pregnancy temperament factors were replaced as predictors by the subscales of those factors that the first analysis indicated as having a significant effect. The results are shown in Table 3. The following significant effects were found: a higher attentional focusing score was associated with better nonverbal IQ at T1, a higher attention score was associated with higher performance in both verbal IQ and nonverbal IQ at T2, and shyness was associated with poorer verbal IQ at T2.

3.2 LONGITUDINAL EFFECTS OF TEMPERAMENT ON COGNITIVE DEVELOPMENT

The results of the longitudinal analysis are shown in Table 4. Effortful control was found to associate with greater improvement in vocabulary from T1 to T2. As in the case of the first analysis, a secondary regression was performed to examine the interaction between effortful control and sex; no statistically significant interaction effect was found ($p > 0.1$ in all cases).

Table 4: The effects of temperament traits at T1 on cognitive development from T1 to T2

	Vocabulary			Similarities			Block Design		
	Beta	CI 95%	p	Beta	CI 95%	p	Beta	CI 95%	p
Effortful Control	1.87	(0.20, 3.53)	0.03	-0.10	(-1.04, 0.85)	0.84	-0.29	(-1.92, 1.35)	0.73
Extraversion/Surgency	0.10	(-1.37, 1.57)	0.89	-0.53	(-1.36, 0.30)	0.21	0.96	(-0.50, 2.41)	0.19
Negative Affectivity	0.00	(-1.47,1.47)	1.00	-0.11	(-0.94, 0.73)	0.80	-0.16	(-1.64, 1.33)	0.83

Cognitive change expressed as change in raw score, temperament traits expressed as z-scores; all scores adjusted for sex, age, and mother's licorice consumption during pregnancy

A further analysis was conducted to predict vocabulary development by effortful control subscales. The results are shown in table 5; no single subscale reached statistical significance ($p > 0.1$ in all cases).

Table 5: The effects of Effortful Control subscales atT1 on Vocabulary development from T1 to T

	Beta	CI 95%	p
Attentional focusing	1.33	(-0.45, 3.11)	0.14
Inhibitory control	0.22	(-1.69, 2.12)	0.82
Low-intensity pleasure	0.30	(-1.41, 2.02)	0.73
Perceptual sensitivity	0.46	(-1.30, 2.21)	0.61

Cognitive change expressed as change in raw score, temperament subscales expressed as z-scores, Sex: 0 = girl, 1 = boy; adjusted for sex, age, and mother's licorice consumption during pregnancy

4 DISCUSSION

4.1 ESSENTIAL FINDINGS

This longitudinal study of 468 mother-child dyads builds on a moderately extensive corpus of prior research on the relationship between temperament and cognitive ability in children, and its results are largely congruent with earlier findings. Those children who displayed greater effortful control, as reported by parents, performed better in tests of verbal and non-verbal intelligence at ages 8 and 12, and showed more improvement in their vocabulary over the intervening years. Furthermore, children who were rated as shy at age 12 performed less well on verbal tasks than more gregarious children. In addition, and unlike as expected, children who displayed greater negative affectivity in parental assessment at age 12 performed better than their more emotionally placid peers. These results are considered in more detail below.

4.2 GREATER EFFORTFUL CONTROL IS INDICATIVE OF BETTER COGNITIVE PERFORMANCE

The foremost finding of thesis the replication of a robust positive association between effortful control and cognitive performance. Those children who were rated by parents as displaying more effortful control performed better on tests of cognitive ability. This effect was found in both follow-ups, four years apart, and in both verbal and nonverbal cognitive tasks, with effect sizes ranging from 0.32 to 0.42. In the context of prior research, these are effects of considerable magnitude: reports of effect sizes greater than 0.4 are all but nonexistent in the literature on temperament and intelligence.

A more detailed inspection found attention to be the foremost aspect of effortful control regarding this effect. With the exception of verbal performance at age 8, for which $p > 0.05$, effect sizes ranged from 0.25 to 0.35 for the two cognitive indices at two follow-ups. It can therefore even be said that, of the effect of higher-order effortful control on cognitive ability, the greater part is attributable to the ability to direct, focus, and maintain attention.

The ability to pay attention to the task at hand is an essential prerequisite of good performance on an intelligence test, so it is clear a priori that exceptionally poor attention should also preclude high cognitive test performance. However, the association between attention and intelligence is so strong that it seems a matter of definition whether attention should be considered, on the one hand, an influence on cognitive performance, or a facilitating tool for its application in a test, or, on the other hand, as simply one aspect of intelligence. This is a point of contention as old as psychometrics, touched on by Spearman (1904) and discussed ever since; Schweizer (2010) provides an overview of the case, emphasizing the shared neurological correlates.

As interesting as the potency of association between attention and cognitive performance is the lack of significant associations between cognitive performance and the other subscales of effortful control. Activation control and inhibition are both strongly implicated in the personality trait of conscientiousness, which is negatively correlated with intelligence (Moutafi, Furnham, & Crump, 2006; Moutafi, Furnham, & Paltiel, 2004), but no negative effect was found for them either. Nevertheless, this result highlights the fact that regardless of the evidence for the validity of higher-order traits, such as effortful control, they are not always preferable to lower-order traits in elucidating particular patterns in interpersonal variation. Sometimes, a particular effect is connected with a specific lower-order trait rather than the more general trait of which it is an aspect.

4.3 SHYNESS INDICATES POORER VERBAL PERFORMANCE AT AGE 12

Another significant effect was found for shyness at age 12: higher scores on shyness dimension associated with lower scores on verbal tasks. Other aspects of introversion were not found to exert an influence on cognitive performance; that is, by the results of this study, it is shyness specifically, not risk aversion or fearfulness, that is linked to poorer verbal performance. The negative effect of shyness on verbal performance at age 12 adds to prior research by Wolfe et al. (2014), who found both concurrent associations between shyness and poorer cognitive performance and a predictive effect for shyness at earlier ages for poorer cognitive performance at later ages in preschool-age children.

The possibility must be considered, however, that rather than being indicative of poorer inherent cognitive ability, shyness may impede responsiveness in the cognitive assessment situation. If, as is to be expected, a shy child exhibits a relative tendency to refrain from speaking when uncertain, and to be reluctant to elaborate on responses, he or she will attain poorer scores on the vocabulary and similarities items of the test in question than a child of equal comprehension of the concepts being assessed who responds more readily; this might be consistent with an effect found more readily in verbal rather than nonverbal assessment, but it sheds no light on why the effect should be restricted to older children. Similarly, it is possible that the causation is the inverse of that suggested earlier, and that children with poorer verbal ability have more unsatisfactory social experiences, due to losing arguments, being misunderstood, and the like, and come to exhibit more social reluctance. Any interpretation of this specific result must be qualified and tentative.

4.4 NEGATIVE AFFECTIVITY IS ASSOCIATED WITH BETTER COGNITIVE PERFORMANCE AT AGE 12

The most surprising of the results was the positive association between negative affectivity and cognitive performance at the later follow-up: higher negative affectivity was found to associate with better cognitive performance, both verbal and nonverbal, at age 12, but not at age 8. The effect sizes were 0.39 and 0.25 for verbal and nonverbal performance, respectively. That is, these effects are by no means marginal: they are in the same range as the fairly large, and much more expected, effects found for effortful control. Whatever the exact causal relationship may be, it is interesting to note that, as in some earlier studies (Maziade, M.M., Cote, R., Boutin, P., Bernier, H., & Thivierge, 1987), higher intelligence was exhibited by children who would be described as "difficult", displaying aggression, negative emotions, and non-compliance.

Knowing that teenagers are moodier overall than preteen children, the possibility suggests itself that the association found may be due to differences in general mental maturation at this age: children who are more mentally developed in general, relative to their chronological age, might display both superior cognitive performance, and a more negatively-tilted emotional profile. Indeed, the change in negative affectivity from age 8 to age 12 displayed small negative correlations with both verbal and nonverbal cognitive performance at age 12 ($r=-0.13$ and $r=-0.08$, respectively), but neither of these effects reached statistical significance ($p=0.08$ and $p=0.27$, respectively).

On the other hand, there is evidence that negative mood improves performance in tests of memory and discrimination and reduced reliance on biased heuristics (Forgas, 2013). According to Forgas (2013), negative mood encourages controlled, analytic approaches that rely on incorporating externally produced, novel information, in comparison with positive mood, which is conducive to approaches relying on preexisting knowledge and assumptions. As the assessment method used in this study for identifying negative affectivity relies on a parent's opinion of the child's proneness to negative emotional responses and therefore a tendency to negative moods, it is entirely to be expected that a beneficial effect of state negativity on performance in cognitively demanding, novel tasks would show up as a positive association between trait negativity and cognitive ability.

That the most prosocial temperament did not go with the best performance on the cognitive test is in contrast with the more frequently found result of all good things clustering together: intelligence, longevity (e.g. Deary, 2010), physical attractiveness (e.g. Banks, Batchelor, & Mcdaniel, 2010), social success (e.g. Gottfredson, 2004), and a plethora of other outcomes tend to be positively correlated. A negative association between prosociality and cognitive performance, if it should prove stable, is an interesting exception.

4.5 EFFORTFUL CONTROL PREDICTS GREATER IMPROVEMENT IN VOCABULARY FROM AGE 8 TO AGE 12

Effortful control was also found to hold predictive value for improvement in children's vocabulary from age 8 to age 12. As in the cases of corresponding effects on both cognitive performance indices at both follow-ups, attentional focusing appears to be responsible for most of the effect in question, although it alone did not reach statistical significance in this study ($p = 0.14$). For the other two individual subtests that were administered at both follow-ups, no significant effects were found to be exerted by any of the three higher-order temperament traits.

It must be noted, that the number of subjects for the longitudinal analysis was much lower (N=194) than for the age-specific analyses (N=301 at T1, N=372 at T2), restricted as it was to those mother-child dyads who participated in both follow-ups. Significant effects should therefore be expected to appear at a lower rate, due to more limited statistical power. Vocabulary may be the one subtest in which the effect was discovered due to being the most strongly g-loaded of the three subtests included in the longitudinal analysis (Weiss, Keith, Zhu, & Chen, 2013).

4.6 OTHER CONSIDERATIONS

Another of the strengths of the current study is the use of well-validated measures of temperament and of cognitive ability. Rothbart's tests on the one hand, and the WISC-R on the other, are the most widely used and extensively studied assessment tools in their respective fields.

Nevertheless, these, like all other tools, are far from perfect, and their interpretation is riddled with caveats. In particular, the reliance on parent report limits us to the level of accuracy of parents' ability to evaluate their children, and for a questionnaire to capture that evaluation. The various temperament subscales agree only to a moderate extent with self-report: Ellis & Rothbart (2001) report correlation coefficients ranging from 0.27 to 0.46 for the EATQ-R subscales. While there is no reason to expect self-assessments of temperament to more accurately reflect whatever underlying traits actually effect behavioral tendencies, it is clear that a considerable degree of noise exists in the instrument.

In regards to cognitive assessment, only four subtests from the full WISC-R were used at each follow-up, somewhat reducing the reliability of the instrument in question; a concern further. Questions may also be raised over whether the focus on verbal and nonverbal components, rather than a general intelligence trait, is warranted: while the subtests used do cluster clearly in these two groups, the division further increases the degree of noise.

Attrition is another concern. While drop-out is a factor in all longitudinal research, the degree of drop-out from the initial questionnaire respondents is considerable in this study. A higher percentage of the T2 participants reported having attained a university-level education, which does correspond in general to greater intelligence, so it is conceivable that children with greater cognitive ability would be slightly overrepresented at T2. On the other hand, both follow-up samples reported a higher mean liquorice consumption than did the original questionnaire respondents, and as earlier research on the same subjects has shown, this has negative implications on cognitive function and a host of other developmental variables (Räikkönen et al., 2009, 2017). While it is highly unlikely that the distribution in cognitive performance would differ so much in the follow-up sample from the population that the results of this study would be invalidated, it is entirely possible that the effect sizes found would differ notably in a more perfectly representative sample.

The follow-up samples do not display other signs of attrition selectivity, but there is no guarantee that some concealed disparity exists between the population, of which the original questionnaire sample should be highly representative, and the two partially overlapping follow-up samples. In particular, temperament and personality could well exert a subtle influence on participation: one would expect social anxiety or low conscientiousness to reduce the probability of accepting the follow-up invitation, and any number of other traits could have a more circuitous effect. Nevertheless, these concerns are shared with all correlational research on longitudinal data, and there is no reason to expect the results of this study to be less than valid on their account. Indeed, they are merely an unavoidable consequence of what must be viewed as two major strengths of this study: on the one hand the large, demographically representative cohort sample, of which exceptionally detailed information was available, and on the other, the long follow-up from birth combined with a repeated assessment design over a 4-year interval.

4.7 CONCLUSIONS

This study clearly shows that the associations between temperament and cognitive performance, during middle to late childhood, are both strong and complex. The finding of the significant part played by attention in cognitive performance, paralleling its role as a fundamental constituent of effortful control, one of the major dimensions of temperament, is well validated and easily comprehended. It is also not surprising that children with greater effortful control would exhibit greater improvement in their vocabulary from age 8 to 12, as the magnitude of this change is a fair index of general increase in knowledge over these years.

The other results of this study do not immediately suggest such an unequivocal interpretation. Shyness may be connected to poorer verbal ability by way of a shared prior causal factor, reduce verbal performance through anxiety and reticence, or result from repeated negative social experiences caused by lack of verbal success. The positive association between cognitive performance and negative affectivity at age 12 is the most tantalizing of the results of this study. Aside from, on the one hand, the possibility of differences in general mental development producing such an association, and on the other, the suggested favorability of negative moods for analytical thinking, the reason for the observed association remains entirely unclear. Should such an effect be observed in later study as well, it will undoubtedly prove an interesting subject for research in its own right.

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