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The genetic architecture of effortful control and its interplay with psychological adjustment in adolescence

Corrado Fagnani [a,*,1], Emanuela Medda [a,1], Guido Alessandri [b], Davide Delfino [a], Cristina D'Ippolito [a], Nancy Eisenberg [c], Maria Antonietta Stazi [a]

[a] Istituto Superiore di Sanità, Centre for Behavioural Sciences and Mental Health, Rome, Italy
[b] Department of Psychology, Sapienza, University of Rome, Italy
[c] Department of Psychology, Arizona State University, USA

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ABSTRACT

The role of genes and environment in the relation between self-regulation and adjustment is unclear. We investigated, with the twin design, genetic and environmental components of the association between effortful control (EC) and indicators of psychological adjustment using adolescents' and parents' reports for 774 twins. Genetic factors explained a substantial proportion of variance in EC (58%) and the outcome variables of optimism (55%), general self-esteem (45%), happiness (48%), and self-derogation (29%). Perceived competence had no significant genetic component. Aside from perceived competence, uncorrelated with EC, phenotypic correlations of EC with measures of well-being/adjustment were moderate and predominantly explained by shared genetic effects. Results suggest a significant genetic contribution in adolescents' EC and in its relation to various aspects of adjustment.

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1. Introduction

Researchers have frequently explored the potential role of stable individual characteristics in social adjustment and emotional competence in adolescence (Jaffari-Bimmel, Juffer, Van IJzendoorn, Bakermans-Kranenburg, & Mooijaart, 2006). Often researchers have stressed the assumed causal link between temperamentally-based individual differences in emotion-related self-regulation and adolescents' psychological and social maladjustment (Eisenberg et al., 2001, 2003; Silk, Steinberg, & Morris, 2003) under the assumption that emotion-related self-regulation and its component skills are basic characteristics, rooted in the genetic endowment of the individuals, that can foster positive development (Eisenberg, Spinrad, & Eggum, 2010). However, the heritability of emotion-related self-regulation has been investigated mostly in infancy or early childhood, and, of particular importance, the roles played by heredity and the environment in explaining the broad role of self-regulation in adjustment are unclear.

We examined these issues using a sample of 774 twins for whom a measure of emotion-related self-regulation (henceforth labeled self-regulation) was obtained from both the adolescent and a parent. The aims of this paper were twofold. First, we estimated the genetic and environmental (shared and nonshared) components of observed variability in measures of regulation and indicators of emotional psychological well-being (i.e., happiness, optimism, and general self-esteem, perceived general competence, and low self-derogation; see Houben, Van Den Noortgate, & Kuppens, 2015). Second, we estimated the degree to which genetic and environmental factors account for the correlations- often reported in literature - between self-regulation and indicators of psychological adjustment in adolescence. One cannot assume that the role of genetics and the environment in the correlation between self-regulation and well-being is the same at all ages. Moreover, given changes during adolescence in prefrontal regulatory processes and other related, potentially opposing sub-cortical processes (such as sensation seeking or impulsivity) that affect the expression of self-regulation (and appear to actually decrease self-regulation during part of adolescence; e.g., Casey, 2015; Luciana, Wahlstrom, Porter, & Collins, 2012; Steinberg, 2010), one cannot assume that the role played by genetic versus environmental factors is the same in adolescence as during other periods of life.

1.1. Effortful self-regulation

Loosely speaking, self-regulation represents a broad construct entailing attentional, cognitive, physiological, and behavioral

* Corresponding author.
E-mail address: corrado.fagnani@iss.it (C. Fagnani).
[1] These authors contributed equally to this work.

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processes that operate in concert to ensure an appropriate level of emotional, motivational, and cognitive arousal (Blair & Diamond, 2008). From a developmental perspective, researchers often investigate self-regulation from a temperament framework using measures of effortful control (Rothbart, Derryberry, & Posner, 1994; Rothbart, Ellis, & Posner, 2011; Rueda, Posner, & Rothbart, 2005). The construct of effortful control (EC) reflects the temperamentally-based component of emotion-relevant self-regulation and captures a set of relatively deliberate control functions needed for voluntary and goal-directed behavior (Rothbart & Bates, 2006). EC pertains to dispositional differences in the abilities to effortfully modulate attention, behavior, and emotion and involves some executive functioning capacities (i.e., planning, detecting errors, assimilating information, etc.; Eisenberg, Hofer, Sulik, & Spinrad, 2014). As highlighted by Rothbart and Derryberry (2002), the constitutional temperamental basis of EC refers to the relatively enduring "makeup" of the organism, influenced over time by heredity, maturation, and experience. The capabilities that are part of EC can be viewed as tools available for self-regulation of emotion and behavior in specific contexts; thus, EC provides the temperamentally based capacities for self-regulation (Eisenberg et al., 2014).

Developmentally, EC represents an early appearing component of child temperament (Kochanska, Murray, & Harlan, 2000; Rothbart & Bates, 1998; Rothbart & Rueda, 2005). Children relatively high in EC, compared to those who are lower, exhibit better social and emotional competence (Bjorklund & Kipp, 1996; Derryberry & Rothbart, 1997; Eisenberg et al., 2003; Kochanska, Murray, & Coy, 1997; Kopp, 1982, 1989), are less likely to develop internalizing and externalizing problems (Eisenberg & Spinrad, 2004; Eisenberg et al., 2001, 2003), and perform better at school (Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Eisenberg, Valiente, & Eggum, 2010). In empirical studies, EC has been associated with peers' (Eisenberg, Fabes, & Murphy, 1996) or teachers' reports (Diener & Kim, 2004) of children's and adolescents' prosocial behavior. Based on a person-centered approach, Veenstra et al. (2008) found that clusters of preadolescents characterized by high levels of prosociality had an elevated level of EC. Other researchers have found that, in early adulthood, EC is positively associated with intimate interpersonal relationships and self-esteem (e.g., Busch & Hofer, 2012), and prosociality (Alessandri et al., 2014; Veenstra et al., 2008), as well as life satisfaction and optimism (Fosco, Caruthers, & Dishion, 2012).

1.2. The genetics of effortful self-regulation

From a neurobiological point of view, available evidence suggests that EC is under the influence of the executive attention network, which is neuroanatomically centered in the anterior cingulate gyrus and areas in the prefrontal cortex (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999; Fan, Flombaum, McCandliss, Thomas, & Posner, 2003). The functioning of this network is related to regulating thoughts, emotion, and action (Posner & Petersen, 1990; Posner, Rothbart, Sheese, & Tang, 2007). The executive attention network appears to undergo progressive maturation, starting to emerge in the first year of life and continuing during childhood into adolescence (Rueda, Checa, & Cómbita, 2012). However, in adolescence, heightened reactivity to emotions and rewards (as reflected in sensation seeking or impulsivity) affects the level of self-regulation and can result in a temporary decline in its level, at least in some contexts (see Casey, 2015).

Given that EC is a component of temperament with neurological correlates, it is not surprising that investigators have assessed the contributions of both genes and environment to EC (Goldsmith, Pollak, & Davidson, 2008). At present, molecular genetic studies suggest that the dopamine D4 receptor gene (Fan, Fossella, Sommer, Wu, & Posner, 2003) and the catechol-o-methyl transferase gene (Blasi et al., 2005) are two of the candidate genes involved in the behavioral expression of EC. Yet more data are necessary in order to evaluate the relations of genes and the environment to EC at different ages.

Previous studies have often been conducted using the classical twin design (Lemery-Chalfant, Doelger, & Goldsmith, 2008; Yamagata et al., 2005). With this design, under certain assumptions (Neale & Cardon, 1992), the effects of genetic ('heritability') and of environmental (both shared within family and individual-specific) factors on one or more traits can be estimated from the comparison between monozygotic (MZ) twins (genetically identical) and dizygotic (DZ) twins (who share half of their genetic background, like ordinary siblings). The results regarding genetic and environmental effects can be extended - within the limitations of each study- to the general population of which the twin population has been shown to be representative in many respects.

Although a number of researchers have used behavioral genetic twin studies to examine the relative contribution of genes and environment to EC, the available evidence regarding the first two decades of life is mostly from samples of infants and young children. The upshot of these studies is that individual differences in EC appear to be substantially heritable. Based on the intraclass correlations in MZ (rMZ) and DZ (rDZ) twin pairs reported in these studies and using the formula $2 * (rMZ\text{-}rDZ)$, we estimated moderate genetic influence for various self-regulation measures in children up to 2 years of age (Gagne & Goldsmith, 2007; Gagne & Saudino, 2006), moderately high genetic effects for children about 3 years old (Gagne & Goldsmith, 2007), and moderately high genetic effects for children about 7-years old (Goldsmith, Buss, & Lemery, 1997; Lemery-Chalfant et al., 2008). After early childhood, behavioral genetics estimates of heritability show some variability across studies, and are often based on highly age-heterogeneous samples. For example, Yamagata et al. (2005) reported a heritability estimate of 49% for EC on a sample of twins varying in age from 17 to 32 years.

The lack of reliable behavioral genetic data for adolescents seems particularly critical in light of recent neurobiological evidence indicating that the effortful regulatory skills associated with EC fluctuate during adolescence (Casey, 2015), although there is prefrontal cortical development (e.g., in terms of interconnections within; Casey, 2013) relevant to executive functioning/self-regulation (Casey, 2013; Casey, Jones, & Hare, 2008; Steinberg et al., 2009). Genes are generally viewed as responsible not only for the stability but also for change in individuals' characteristics (e.g., Hopwood et al., 2011; Lewis & Plomin, 2015; Plomin, 1986). Thus, a high heritability coefficient for a trait in a specific phase of life indicates that the expression of that trait at that age is at least partly dependent on genetic mechanisms. Yet the fact that genetic factors appear to be a major contributor to the expression of EC does not mean that the observed influence of EC on psychological adjustment is governed only by genes (Goldsmith et al., 2008) or that the genetic influence is stable with age.

1.3. Effortful control and psychological adjustment in adolescence

Over the past several decades, researchers have related both absolute level of EC and rate of change over time in EC to a wide range of developmental outcomes in adolescence such as general self-esteem (Robins, Donnellan, Widaman, & Conger, 2010), self-perceived general competence (DiBiase & Miller, 2012; Rhoades, Greenberg, & Domitrovich, 2009), the tendency to harbor depressive feelings (Davenport, Yap, Simmons, Sheeber, & Allen, 2011), happiness (Fosco et al., 2012), and optimism (Lemola et al., 2010). Given that the effortful self-regulation/EC is complex in ado-

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