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Commonality between executive functioning and effortful control related to adjustment

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Abstract

This study examined the association between executive functioning (EF) and effortful control (EC), and tested whether cognitive control as the commonality of EF and EC, predicted competence and internalizing and externalizing symptomatology in children (N = 218, 6–8 years) and adolescents (N = 157, 13–14 years). Confirmatory factor analyses suggested cognitive control—inhibitory control and attentional control—as a significant overlap between EF and EC. Structural equation modeling analyses indicated that the cognitive control latent factor was associated with competence and internalizing and externalizing symptomatology among children and externalizing symptomatology among adolescents. The results provide evidence that inhibitory control and attentional control are the commonality between EF and EC and highlight that they are linked with positive and negative adjustment outcomes.

Keywords

cognitive control; inhibitory control; attentional control; executive functioning; effortful control; adjustment

Executive functioning (EF) and effortful control (EC) have received substantial attention in studies of the development of self-regulation, yet there is a paucity of evidence regarding the empirical association between EF and EC and potential developmental differences between children and adolescents in this association. Many researchers use these terms

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interchangeably, leading to debate over the underlying components of these constructs (McClelland & Cameron, 2012). There have been calls for conceptual clarity of the constructs of EF and EC (Nigg, 2017; Zhou, Chen, & Main, 2012). We empirically tested the theoretical views proposing that cognitive control—i.e., inhibitory control and attentional control—is the commonality between EF and EC (e.g., Zhou et al., 2012) and examined whether the association between EF and EC may differ between children and adolescents. We further tested functional significance of cognitive control by examining its associations with behavioral adjustment outcomes among children and adolescents.

We view inhibitory control and attentional control as lying at the core of both EF and EC and representing cognitive control, which is defined as the ability to flexibly adjust behavior in the context of dynamically changing goals and task demands' (Carter & Krus, 2012, p. 89). The way we operationalize EF and EC acknowledges both the overlapping and separable nature of the two constructs. EF is typically associated with the prefrontal cortex and is a set of general purpose control mechanisms that regulate goal-directed behavior (Best & Miller, 2010); thus, EF is considered a core component of self-regulation (Miyake & Friedman, 2012). According to Miyake's original framework (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000), there are three foundational EF dimensions. *Updating* is the constant monitoring and rapid addition/deletion of information in working memory. *Inhibition* is the purposeful overriding of prepotent responses. *Shifting* involves cognitive flexibility, or the ability to switch between tasks or mental sets. With respect to these three primary EF dimensions, individual differences exhibit both unity and diversity, meaning that different EF dimensions are correlated while also demonstrating some separability (Miyake & Friedman, 2012; Best & Miller, 2010). Developmental studies point toward unidimensionality of EF among younger children (Wiebe et al., 2011), separation of working memory from inhibition and shifting in mid-to-late childhood, and differentiation into a three-factor structure in adolescence (Lee, Bull, & Ho, 2013).

EC refers to the efficiency of executive attention, including the ability to suppress a dominant response and to activate a subdominant response (Rothbart & Bates, 2006), thus it shares some features with EF (Allan & Lonigan, 2011). EC is viewed as a dispositional representation that represents top-down control used in the service of self-regulation (Nigg, 2017). Similar to EF, EC is associated with frontal lobe functioning (Derryberry & Rothbart, 1997; Nigg, 2017; Spielberg, Miller, Heller, & Banich, 2015). Developmentally, by 6 or 7 years of age, the construct of EC is represented by a factor defined by scales measuring inhibitory control, attentional control, perceptual sensitivity, and pleasure from low intensity stimulation (Derryberry & Rothbart, 1997). Among early adolescents, EC is represented by a factor constructed using scales measuring inhibitory control, attentional control, and activation control (Capaldi & Rothbart, 1992).

The current view of developmental psychopathology emphasizes a critical role for EF and EC in the development of behavioral and emotional problems (Diamond, 2013; Rothbart, Derryberry, & Posner, 1994). To date, no study has examined the possibility that inhibitory control and attentional control are at the core of both EF and EC and contribute to positive and negative adjustment outcomes. Past research on EC has demonstrated that low EC (measured by behavioral performance and informants' reports) is related to high levels of

externalizing symptomatology as well as internalizing symptomatology among children and early adolescents (Eisenberg et al., 2005, 2009; King, Lengua, & Monahan, 2013; Lengua et al., 2015; Murray & Kochanska, 2002; Oldehinkel, Hartman, Ferdinand, Verhulst, & Ormel, 2007). There is also evidence that EC is positively related to social competence among children at risk for psychopathology (Dennis, Brotman, Huang, & Gouley, 2007).

Compared to EC, less research is available on the effects of EF on psychopathology outcomes among typically developing children and adolescents. Taking a dimensional approach, as opposed to an extreme-groups approach (i.e., comparing those with and without clinical diagnoses), helps us to evaluate the associations between EF and a broad range of adjustment. Although meta-analysis suggests stronger effects of EF on psychopathology in clinical samples compared to typically developing samples (Schoemaker, Mulder, Dekovi, & Matthys, 2013), EF measured in clinical samples may be contaminated by the presence of other serious psychiatric disorders that can compromise EF as well as often uncontrolled ongoing treatment effects. One study examined the association between executive control which is closely related to EF (defined by top-down abilities that enable the execution of an action requiring the active maintenance of information) and problem behaviors in a community sample of preschoolers (Espy, Sheffield, Clark, & Moehr, 2011). The results revealed that the executive control latent factor (based on laboratory tasks) was significantly related to hyperactive behaviors, attention problems, and disinhibition behaviors, but not emotional dysregulation behaviors. Another study demonstrated that earlier EF (measured by behavioral performance) was associated with later externalizing symptomatology (controlling for the autoregressive effects of earlier externalizing symptomatology) spanning early childhood through middle childhood in a community sample (Sulik et al., 2015). In a longitudinal community sample spanning middle childhood through middle adolescence, better EF (measured by behavioral performance) reduced the likelihood of experiencing problems in peer relationships later on (Holmes, Kim-Spoon, & Deater-Deckard, 2016). Finally, there is evidence that adolescents with greater neural activation during an EF task that taxes cognitive/attention network exhibited decreases in social competence over time, particularly in chaotic home environments (Kim-Spoon, Maciejewski, Lee, Deater-Deckard, & King-Casas, 2017).

Within the neuroscience literature, there are reports that potentially address the issue of common processes of EF and EC. Previous studies have identified brain regions involved in inhibitory control, including the basal ganglia (such as caudate, putamen, globus pallidus), that are thought to be involved in inhibition of inappropriate responses, as well as prefrontal regions (such as inferior, medial, and dorsolateral prefrontal cortices) which receive inputs from the limbic basal ganglia thalamocortical circuit and represent and maintain relevant information for goal directed behaviors (Aron, Robbins, & Poldrack, 2014; Booth et al., 2003; Casey, Durston & Fossella, 2001). In particular, Aron and colleagues have argued the right inferior frontal gyrus (RIFG) as the critical prefrontal cortex node for inhibitory control (Aron et al., 2014). Indeed, neuroimaging studies demonstrate the involvement of the RIFG in the inhibition of responses as well as attentional reorientation and shifting (Corbetta & Shulman, 2002; Dodds, Morein-Zamir, & Robbins, 2011; Hampshire & Owen, 2006). In particular, Dodds and colleagues (2011) proposed that the right inferior frontal gyrus region operates at the interface of inhibitory control and attentional control, playing a key role in

the integration of bottom-up, sensory information with top-down, response-related information to facilitate flexible, goal-directed behavior. Although behavioral studies examining the association between EF and EC are rare, Bridgett and colleagues (2013) examined factor correlations between EF and EC among young adults and reported that EC (based on self-reports of inhibitory control, attentional control, and activation control) was correlated with EF-updating/monitoring (based on behavioral task indicators) but not EF-inhibitory control (based on behavioral task indicators). To date, however, research has not investigated whether inhibitory control and attentional control can be seen as the cognitive control commonality between EF and EC that are related to adjustment outcomes in children and adolescents.

In the present study, we used two cross-sectional samples of children and adolescents to address three major gaps in the literature. First, although theoretical work describes a *conceptual* overlap between EF and EC (e.g., Zhou et al., 2012), the literature lacks evidence of rigorous measurement modeling on the *empirical association* between EF and EC. To fill this gap and enhance conceptual clarity regarding the constructs of EF and EC, we estimated the factorial correlations between the two factors of EF and EC, first using indicators based on Miyake's theory for EF and Rothbart's theory for EC, and then using indicators of inhibitory and attentional control only. In addition, we tested an alternative model that added a third factor which loaded on only the inhibitory and attentional control indicators to the model with two factors of EF (based on Miyake's theory) and EC (based on Rothbart's theory). The second gap in evidence is whether there are developmental differences across childhood and adolescence in the EF-EC association. This lack of evidence can be attributed to the challenge of heterotypic continuity—i.e., the manifestation of the same underlying construct through different behavioral presentations at different developmental periods (Cicchetti & Rogosch, 2002; Petersen, Hoyniak, McQuillan, Bates, & Staples, 2016). We constructed latent factors of EF and EC based on manifest indicators that (1) are based on well-accepted theories—i.e., the dimensions of EF based on Miyake and colleagues' (2000) theoretical framework, and the dimensions of EC based on Rothbart and colleagues' (1994) theoretical framework, and (2) are presumed to be “developmentally appropriate” because behavioral manifestations of EF and EC are thought to change across development, consistent with the notion of heterotypic continuity (Petersen et al., 2016). In evaluating EF-EC factorial associations across the two age groups, we addressed heterotypic continuity by focusing on factorial correlations (i.e., associations among latent factors) instead of factor loadings (i.e., associations between latent factors and manifest indicators) across ages. This approach is consistent with the idiographic filter concept by Nesselroade and Molenaar (2016) in which factors “filter” idiosyncrasy that is irrelevant to the purpose of establishing lawful relations among the primary factors by allowing factor loadings to reflect idiosyncratic features of subgroups. Third and finally, EF and EC, as two closely related self-regulation constructs that play important roles in behavioral adjustment in childhood and adolescence, have not been systematically integrated. We explored whether cognitive control commonality between EF and EC, as a single latent factor represented by both inhibitory control and attentional control, may be associated with competence and internalizing and externalizing symptomatology. This goal was in part motivated by the findings in neuroscience indicating the functional role of inferior frontal cortex that

integrates inhibitory and attentional control to produce flexible, goal-directed behavior (Dodds et al., 2011). There are studies of EC or EF that used both informant report and behavioral task performance approaches (e.g., see Diamond, 2013 and Eisenberg, Morris, & Spinrad, 2005 for reviews). In most studies, however, EC has been measured using questionnaire data, whereas EF has been measured using behavioral task performance data. These practices reflect, in part, two different research traditions in which EC has been studied from a temperament-based approach, heavily relying on parent and self-report, whereas EF has been studied from the clinical neuropsychology approach, heavily relying on behavioral performance (Nigg, 2017). Because behavioral adjustment is typically measured by questionnaire data from knowledgeable informants, the magnitude of the associations between task-based measures of EF and questionnaire-based measures of behavioral adjustment may be underestimated. In contrast, the magnitude of the associations between questionnaire-based measures of EC and questionnaire-based measures of behavioral adjustment may be overestimated due to shared method effects (e.g., Campbell & Fiske, 1959). In the current analysis, we applied latent factor modeling to estimate a cognitive control commonality factor that integrates informant reports and behavioral performance data while also estimating method variance.

METHOD

Participants

Participants were 218 children (50% male) aged 6 to 8 years (shortly after transitioning into middle childhood, $M = 6.65$, $SD = 0.45$) and 157 adolescents (52% male) aged 13 to 14 years (shortly after transitioning into adolescence, $M = 14.13$, $SD = 0.54$). For both children and adolescents, about 80% were White, 12% were African American, and 6% were other. For children, 9% of their mothers completed a high school education, 20% some college education, 40% bachelor's degree, and 31% graduate degree. For adolescents, 35% of their primary caregivers (133 mothers, 19 fathers, and 5 others) completed a high school education, 23% some college education, 24% bachelor's degree, and 18% graduate degree.

Procedure

Participants were recruited by diverse advertisement methods including flyers, commercial mailing lists, and e-mail distributions. The children were recruited and data were collected at two research locations, with each location site recruiting half of the total sample. Adolescents were recruited and data were collected at one of the sites recruiting the child sample. Data collection took place at each university's research labs, and parent, child, and adolescent participants received an honorarium. All procedures were approved by the institutional review boards of the universities.

Measures

Executive functioning (EF).—EF tasks were selected to represent the three foundational EF dimensions according to Miyake's theoretical framework (Miyake et al., 2000). For children, EF was assessed using the following measures. (1) *Updating: Digit Span Task* (Garon, Bryson, & Smith, 2008). Children were presented with a series of digits and instructed to repeat the sequence backwards. The highest span in which the child could

repeat the entire digit sequence in correct backwards order for two sequences of the same number of digits was used. (2) *Shifting: Dimensional Change Card Sort (DCCS: Zelazo, Frye, & Rapus, 1996)*. Children were instructed to sort cards based on two dimensions (i.e., color, shape). Children first sorted six cards by one dimension (pre-switch; counterbalanced across participants) and then were instructed to switch and sort the remaining six cards by the other dimension (post-switch). Performance was indicated by the proportion of correct post-switch responses. (3) *Inhibition: Number Stroop (Ruffman, Rustin, Garnham, & Parkin, 2001)*. The number-based computerized Stroop task had three conditions: letters, numbers, and mixed. Emphasis was placed on the mixed condition, which is considered to induce the most conflict because it includes trials from both the letter and number conditions. Children were told to count either letters (“AAA” = 3) or number digits (“555” = 3) that appeared on the computer screen and to indicate their response on the keyboard. Practice trials were provided. The variable of interest was mean reaction time for correct responses in the mixed condition.

For adolescents, EF was assessed using the following measures. (1) *Updating: Digit Span Task (Stanford Binet Intelligence Test, Fourth Edition; Thorndike, Hagen, & Sattler, 1986)*. Backward raw scores were calculated by subtracting the total number of attempted items failed from the highest span administered. (2) *Shifting: Wisconsin Card Sort Task (WCST-64; Heaton & PAR staff, 2003)*. WCST required participants to identify the rule to properly sort the card (based on shape, color, or quantity) and successfully update and shift to the new sorting rules when they occur. Perseverative errors were used indicating mistakes made by continuously using the same incorrect matching rule, reflecting difficulty with attention shifting. (3) *Inhibition: Multi-Source Interference Task (MSIT; Bush, Shin, Holmes, Rosen, & Vogt, 2003)*. MSIT required participants to indicate which of three numbers is different from the other two. In neutral conditions, target numbers were congruent with presented locations. In interference conditions, target numbers were incongruent with the target locations. Intraindividual variability in reaction time was indexed by intraindividual standard deviations (ISDs) across correct response latency trials of interference conditions (MacDonald, Karlsson, Rieckmann, Nyberg, & Bäckman, 2012). Composite scores were created by averaging standardized scores of accuracy difference (i.e., interference condition minus neutral condition) and reverse coded ISDs of reaction time ($r = .51, p < .001$).

Effortful Control (EC).—For children, mothers’ reports on the Child Behavior Questionnaire Short Form (CBQ; Putnam & Rothbart, 2006) were used. EC ($\alpha = .84$) consisted of inhibitory control, attention focusing, low intensity pleasure, and perceptual sensitivity subscales. For adolescents, self-reports as well as parent reports on the Early Adolescent Temperament Questionnaire-Revised Short Form (EATQ-R; Capaldi & Rothbart, 1992) were available. EC ($\alpha = .82$ for self-reports and $\alpha = .87$ for parent reports) consisted of inhibitory control, attention, and activation control subscales.

Competence and Internalizing and Externalizing Symptomatology.—For children, competence and behavior problems were assessed using mothers’ reports on the Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2001). For adolescents, self-

reports on the Youth Self Report (YSR; Achenbach & Rescorla, 2001) were used. We used the subscales of competence (e.g., participation in organizations, number of friends, time spent with friends, gets along with siblings, peers, and parents; $\alpha = .68$ for CBCL and $\alpha = .55$ for YSR, Achenbach & Rescorla, 2001), internalizing symptomatology (e.g., anxious depressed, withdrawn depressed, somatic complaints; $\alpha = .90$ for CBCL and YSR, Achenbach & Rescorla, 2001), and externalizing symptomatology (e.g., aggressive behavior, rule breaking behavior; $\alpha = .94$ for CBCL and $\alpha = .90$ for YSR, Achenbach & Rescorla, 2001).

RESULTS

Table 1 presents descriptive statistics for all study variables. Prior to analyses, all EC and EF variables were standardized and several univariate outliers ($n = 4$ for the DCCS and $n = 5$ for WCST) that deviated more than 3.29 *SD* (Tabachnick & Fidell, 2001) from the mean were Winsorized. Multivariate general linear modeling (GLM) analyses testing the effects of demographic characteristics on outcomes revealed no significant effects of race on the outcomes of competence and internalizing and externalizing symptomatology ($p = .147$ for children and $p = .409$ for adolescents for Wilks' Lambda; contrasting White vs. Non-White). However, maternal education (four categories including high school completion, some college education, bachelor's degree, and graduate degree) was significantly associated with the outcomes for children ($p = .042$ for Wilks' Lambda) suggesting that it was predictive of competence ($p = .006$) but not internalizing and externalizing symptomatology ($p = .253$ and $.085$ respectively). Parental education was not significantly associated with the three outcomes for adolescents ($p = .142$ for Wilks' Lambda). Therefore, maternal education was included as a covariate in the latent factor analyses testing the effects of the cognitive control factor on adjustment outcomes only for children. We did not test age and sex effects because the outcome variables were *t*-scores that were standardized for age and sex. We performed the latent factor analyses using structural equation modeling (SEM), based on maximum likelihood estimation, separately for the child and adolescent samples. With respect to missing data, one adolescent's MSIT data were excluded due to extremely low accuracy (16%) and we used Full Information Maximum Likelihood (FIML) estimation to account for missing data.

Table 2 presents correlations for the study variables that were used SEM analyses. We conducted a series of confirmatory factor analyses (CFA) to examine the association between EF and EC latent factors separately for children and adolescents. EC latent factors were based on parents' reports on the CBQ for children, and adolescents' self-reports on the EATQ for adolescents (see Figures 1 and 2). First, two factor CFA using the full model (involving all EF and EC indicators) demonstrated moderate correlations between EF and EC factors for both children ($r = .27, p = .057$) and adolescents ($r = .31, p = .029$). Model fits were acceptable and all factor loadings were significant (see Figures 1 and 2). Second, the trimmed model retained only inhibitory control and attentional control dimensions (i.e., Number Stroop and DCCS for children and MSIT and WCST for adolescents for EF; and Inhibitory Control and Attention Focusing for children and Inhibitory Control and Attention for adolescents for EC). For both children and adolescents, the factor correlation between EF and EC increased by 41% for children ($r = .38, p = .018$) and 65% for adolescents ($r = .51, p$

< .000). Model fits were acceptable and all factor loadings were significant for these trimmed models (see Figures 1 and 2).

An alternative approach to test commonality of EF and EC was to add a third factor which loaded on only the inhibitory and attentional control indicators to the full model (involving all EF and EC indicators and estimating the covariance between the EC and EF factors). This three factor model showed acceptable model fits for children ($\chi^2 = 9.87$, $df = 9$, $p = .361$, CFI = 1.00; RMSEA = .02) and adolescents ($\chi^2 = 8.85$, $df = 4$, $p < .001$, CFI = .97; RMSEA = .09). For children, all factor loadings were significant for both EC and EF factors, but the third factor had three significant factor loadings (DCCS, CBQ-Inhibitory Control, and CBQ-Attention Focusing) and one non-significant factor loading (Number Stroop). For adolescents, all factor loadings were significant for EC, but EF had two significant factor loadings (Digit Span and MSIT) and one non-significant factor loading (WCST). None of the factor loadings for the third factor for adolescents (MSIT, WCST, EATQ-Inhibitory Control, and EATQ-Attention) were significant. The weak factor loadings for the third factor suggest that there is insufficient evidence for a broad construct that exists separately over and above the constructs of EF and EC.

Next, we performed latent factor SEM in which a common factor of inhibitory control and attentional control—the commonality of EF and EC—is associated with adjustment outcomes of competence and internalizing and externalizing symptomatology, separately for children and adolescents. The cognitive control latent factor was constructed based on inhibitory control and attentional control dimensions from both EF and EC: CBQ- inhibitory control, CBQ-Attention Focusing, Number Stroop, and DCCS for children; and EATQ- inhibitory control, EATQ-Attention, WCST, and MSIT for adolescents. We systematically tested the effect of the method confound (i.e., EC is measured completely based on questionnaire data versus EF is measured completely based on behavioral tasks) by estimating the covariation between the residuals for the variables assessed by the same method (e.g., sharing the same questionnaire method; Kenny & Kashy, 1992). We tested the significance of such method variances by comparing models with and without estimating method variances using χ^2 difference tests (Bollen, 1989). If there are no systematic method variances, then the fit of the simpler model (the one without estimating method variances) should not be significantly worse than the one estimating method variances, which is indicated by non-significant chi-square differences.

We first fit the model in which the common latent factor predicted the three outcomes without correlations among residuals. In the subsequent models, we introduced correlations among residuals in order to specify common-method variance. Due to the model identification problem (i.e., insufficient degrees-of-freedom), we began with the model without correlations among residuals and added within-construct residual correlations and then cross-construct residual correlations, one step at a time. We also kept only significant residual correlations by trimming non-significant ones.

For children, maternal education was initially included as a covariate (predicting competence and being correlated with the cognitive control factor) in the latent factor analyses testing the statistical effects of the cognitive control factor on adjustment outcomes.

Model 1 without residual correlations showed a poor fit ($\chi^2 = 93.00$, $df = 19$, $p < .001$, CFI = .74; RMSEA = .13). Next, Model 2 added residual correlations only between indicators within the same construct (i.e., between the two EC indicators, between the three EF indicators, and between the three outcome indicators). The model fit improved significantly ($\chi^2 = 35.99$, $df = 14$, $p = .001$, CFI = .92; RMSEA = .09; $\chi^2 = 57.01$, $df = 5$, $p < .001$). Four significant residual correlations were kept (between CBQ-inhibitory control and CBQ-Attention Focusing, between DCCS and Number Stroop, between competence and externalizing symptomatology, and between internalizing symptomatology and externalizing symptomatology). Next, Model 3 added crossconstruct residual correlations between the two indicators of EC and the three outcome variables because they were based on questionnaire data ($\chi^2 = 23.32$, $df = 9$, $p = .004$, CFI = .94, RMSEA = .09). The improvement in model fits was significant ($\chi^2 = 12.67$, $df = 5$, $p = .03$). Therefore, we finalized the model by retaining only three significant residual correlations: between CBQ-inhibitory control and CBQ-Attention Focusing, between internalizing symptomatology and externalizing symptomatology, and between CBQ-inhibitory control and externalizing symptomatology. Because maternal education was not significantly associated any outcomes, it was excluded. This Model 4 showed a good fit ($\chi^2 = 31.35$, $df = 11$, $p = .001$, CFI = .92, RMSEA = .09). As shown in Figure 3, in the most parsimonious Model 4, all factor loadings of the cognitive control latent factor were significant and the common factor significantly predicted all three outcomes: competence ($b = 4.58$, $SE = 1.04$, $p < .001$), externalizing symptomatology ($b = -4.48$, $SE = 0.90$, $p < .001$) and internalizing symptomatology ($b = -2.10$, $SE = 0.75$, $p = .005$).

Turning to the results for adolescents, the model without residual correlations showed a poor fit ($\chi^2 = 36.55$, $df = 11$, $p < .001$; CFI = .81; RMSEA = .12). Next, we added residual correlations only between indicators within the same construct (i.e., between the two EC indicators, between the three EF indicators, and between the three outcome indicators). The resulting model showed improvement in model fit compared to the model without residual correlations as shown in multiple fit indices ($\chi^2 = 26.41$, $df = 9$, $p = .002$; CFI = .87; RMSEA = .10; and $\chi^2 = 10.14$, $df = 2$, $p = .01$). Two significant residual correlations were kept (between WCST and MSIT and between internalizing symptomatology and externalizing symptomatology). Next, we added cross-construct residual correlations between the two indicators of EC and the three outcome variables, as they were based on questionnaire data. The model fit of this model was good and the model fit was significantly better than that of the model without cross-construct residual correlations ($\chi^2 = 4.03$, $df = 6$, $p = .672$; CFI = 1.00; RMSEA = .00; and $\chi^2 = 22.38$, $df = 3$, $p < .001$).

We further trimmed this model by keeping only significant residual correlations, including between WCST and MSIT, between internalizing symptomatology and externalizing symptomatology, between EATQ-inhibitory control and externalizing symptomatology, between EATQ-inhibitory control and internalizing symptomatology, and between EATQ-Attention and externalizing symptomatology. However, the results indicated non-positive definite covariance matrix of the residual variances with an out-of-range correlation between EATQ-inhibitory control and internalizing symptomatology, thus we fixed it to zero. This final model showed a good fit ($\chi^2 = 13.00$, $df = 10$, $p = .224$, CFI = .98, RMSEA = .04). As shown in Figure 4, all factor loadings of the cognitive control latent factor were significant

and the common factor significantly predicted externalizing symptomatology ($b = -3.73$, $SE = 1.13$, $p < .001$) but not internalizing symptomatology ($b = -1.53$, $SE = 1.18$, $p = .194$) or competence ($b = 1.66$, $SE = .93$, $p = .075$).

DISCUSSION

To fill the gap in the literature regarding the associations between EF and EC and common underlying components of these constructs, we performed a series of latent factor analyses to rigorously test factor correlations between EF and EC, as well as the convergence between EF and EC, by focusing on cognitive control (inhibitory control and attentional control) as the commonality between them. Our factor analysis results demonstrated moderate correlations (with medium effect sizes) between EF and EC factors both for children and adolescents when involving the dimensions of EF based on Miyake and colleagues' (2000) theoretical framework and the dimensions of EC based on Rothbart and colleagues' (1994) theoretical framework. Our data further supported Zhou and colleagues' (2012) theoretical proposal that inhibitory control and attentional control are common components of EF and EC. That is, by retaining only those indicators that represent inhibitory control and attentional control dimensions for the EF and EC factors, the overlap between these two constructs increased for both children and adolescents. This overlap may in part reflect the common neurobiological processes between EF and EC, which have been shown in the involvement of the right inferior frontal gyrus in inhibitory control and attentional control (Corbetta & Shulman, 2002; Dodds et al., 2011; Hampshire & Owen, 2006; see Aron et al., 2014 for review). Importantly, inhibitory control and attentional control appear to be conceptually and developmentally converging aspects of self-regulation and they may work together in the regulation of behavior for successful adjustment.

Given substantial differences in measurement (including tasks and informants) as well as other possible differences between the two samples that could contribute to the association between EF and EC, caution is required to compare the findings between children and adolescents. Past studies have shown that EF becomes increasingly differentiated throughout childhood (e.g., Huizinga, Dolan, & van der Molen, 2006; Lee et al., 2013). For example, in a longitudinal study following children from 8 years to 10 years of age, factor structure of EF changed from one-factor to a two factor structure where working memory was separable from, yet moderately related to, inhibition and shifting (Brydges, Fox, Reid, & Anderson, 2014). In light of such findings, our findings of the significant EF-EC correlations for both age groups suggest continuity in the overlap between inhibitory control and attentional control despite the EF dimensions becoming more differentiated with age.

The current findings provide empirical evidence that support theoretical proposal that inhibitory control and attentional control may be common processes between EF and EC that contribute to the association between them (Zhou et al., 2012). However, the commonality of inhibitory control between EF and EC appears to be inconsistent with findings by Bridgett and colleagues (2013) who reported non-significant factor correlations between EC and EF-inhibitory control among young adults. Further research is warranted to examine how EF-EC association may change throughout the lifespan. Methodologically, one caveat regarding task selection is that EF and processing speed become more distinct with

age (e.g., Lee et al., 2013). In the study by Bridgett and colleagues, inhibitory control was measured solely based on a Stroop-like color word interference task; it is possible that this task measured mainly processing speed among young adults in their study, contributing to a lower correlation between EC and EF-inhibitory control.

Our latent factor modeling testing the association between cognitive control commonality factor and adjustment outcomes demonstrates a way to model the overlap between EF and EC. Doing so provides a more accurate estimate of the predictive effect of cognitive control as a major contributor to variance in child and adolescent adjustment. Our results further provide some insights regarding possibly differential roles that the cognitive control factor may play in children's versus adolescents' adjustment. For children, the cognitive control factor was related to all three adjustment outcomes of competence and internalizing and externalizing symptomatology. This finding implies that inhibitory control and attentional control may be responsible for the contributions of EF and EC to healthy adjustment in children (e.g., Eisenberg et al., 2005, 2009; see Diamond, 2013 for review). In particular, our finding of the association between the cognitive control factor and competence in children is consistent with the existing work suggesting that those who are better able to self-control demonstrate higher quality relationships (see Farley & Kim-Spoon, 2014 for review). For example, children who are better able to behaviorally self-regulate are also more socially competent (McKown, Gumbiner, Russo, & Lipton, 2009), and those with high executive functioning (based on parent reports and behavioral performance) are less likely to experience peer rejection and victimization (Holmes et al., 2016). Taken as a whole, the findings suggest that children with better cognitive control are expected to exhibit greater competence through a variety of mechanisms that serve to improve their ability to foster positive interactions with peers.

For adolescents, most research has examined EC (rarely EF) in linking with adjustment outcomes and showed that EC is negatively related to externalizing and internalizing symptomatology and positively related to social competence (King et al., 2013; Oldehinkel et al., 2007). Focusing on cognitive control that underlies EF and EC, however, reveals that it was a significant predictor of externalizing symptomatology, but not internalizing symptomatology or competence among adolescents. Our finding is consistent with earlier findings by Young and colleagues (2009) who found inhibitory control to be an important mechanism underlying vulnerability to adolescent externalizing symptomatology. Adolescence is known for the salience and surge of reactivity involving negative affect, particularly around puberty (Casey, 2015). Current developmental cognitive neuroscience theories emphasize imbalances in adolescent brain development, stemming from rapid development of subcortical functioning in conjunction with slow development of prefrontal functioning (Casey, Getz, & Galvan, 2008; Ernst, Pine, & Hardin, 2006). According to these imbalance perspectives, adolescents with high negative affect may be vulnerable to internalizing symptomatology, particularly when their prefrontal functioning related to cognitive control is poor. Future research should examine *interaction* effects between the cognitive control factor and negative affect related to adjustment outcomes. Such modulating effects of the cognitive control factor may be prominent particularly for internalizing symptomatology where the regulation of emotional reactivity is critical (e.g., Blair & Razza, 2007).

From a methodological viewpoint, the current study attempted to address a couple of challenges that are common in developmental research. First, consistent with the notion of heterotypic continuity (Petersen et al., 2016), we used age-appropriate measures for EF and EC by utilizing EF behavioral measures that represent three theoretical dimensions proposed by Miyake and colleagues (2000) and the widely used EC questionnaire measures by Rothbart and colleagues (Capaldi & Rothbart, 1992; Putnam & Rothbart, 2006). In a recent review, for example, Petersen and colleagues (2016) demonstrated that most behavioral tasks for inhibitory control comparable to the CBQ among young children show limited age ranges of usefulness due to ceiling/floor effects (e.g., less than 3 years of developmental span) between age 3 to 7 years. Thus, such tasks are unlikely to be developmentally appropriate or sufficiently sensitive for children in middle to late childhood and adolescents. In addition, to address heterotypic continuity, we chose to focus on evaluating invariance in the factorial correlation between EF and EC latent factors while allowing idiosyncratic aspects of observed/unobserved variable relations (Nesselroade & Molenaar, 2016) between children and adolescents. Second, in our data, EC was measured by questionnaires and EF was measured by behavioral tasks. We addressed the possible method confounding by estimating covariation between the residuals for the variables assessed by the same method. We found that controlling for method-specific effects in general contributed to improving model fit, suggesting the importance of considering method variances.

Limitations of the current study suggest fruitful directions for future research. First, the cross-sectional design and analyses do not allow us to infer causality in the identified associations, and such inferences should be examined in future longitudinal studies. Second, future research examining the association between EC and EF constructs would benefit from using multimethod approaches for assessing EC and EF to address the limitation of the current study—i.e., the confounding of assessment method and construct (i.e., EC measured by questionnaires and EF measured by behavioral tasks). Third, internal consistency estimate was relatively low for the competence measure for adolescents. However, low reliability has a downward bias on estimating effects (Furr & Bacharach, 2008). Thus, effects found in the current study could have been stronger, not weaker, if the competence score had demonstrated higher reliability. Finally, from a methodological viewpoint, we acknowledge the problem of ‘task impurity’ in the use of EF tasks that tap into multiple dimensions of EF (Miyake et al., 2000). For example, we used the sorting tasks (i.e., WCST and DCCS) as tasks that primarily assess attention shifting; however, research indicates that they also require the use of working memory (e.g., Davidson, Amso, Anderson, & Diamond, 2006). It is encouraged that future researchers employ multiple tasks to assess different subcomponents of EF and use a latent variable approach that captures what is shared among the multiple tasks for each EF dimension, which will alleviate the task impurity problem.

In closing, although there have been arguments regarding conceptual similarities between EF and EC, empirical research has rarely examined the intercorrelations of these constructs, particularly among children and adolescents. We applied latent variable modeling to present evidence for the conceptual and empirical overlap between EF and EC factors, focusing on cognitive control—based on inhibitory control and attentional control. Our results provide evidence for the important role of cognitive control, the commonality between EF and EC, in the development of internalizing and externalizing symptomatology and competence that

appear to be age dependent. Future research is required that will provide prospective longitudinal analyses that can reveal more precisely the developmentally typical versus atypical forms of individuals' trajectories of inhibitory control and attentional control, as well as the connections between those trajectories and the development of psychiatric and neurological disorders throughout childhood and adolescence.

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Highlights

- Examines the link between executive functioning (EF) and effortful control (EC).
- Cognitive control represents the commonality between EF and EC.
- Cognitive control predicts positive and negative adjustment outcomes.

Figure 1.

Modeling fitting results of the confirmatory factor analysis of the association between executive functioning and effortful control among children. Standardized coefficients are listed for the full model/the trimmed model that retained only attention and inhibitory indicators (*in italics*). NA = Not Applicable. Model fits: $\chi^2 = 26.96$, $df = 13$, CFI = .93 and RMSEA .07 for the full model; $\chi^2 = 1.22$, $df = 3$, CFI = 1.00 and RMSEA .00 for the trimmed model ($\chi^2 = 25.84$, $df = 10$, $p = .004$). * $p < .05$.

Figure 2.

Modeling fitting results of the confirmatory factor analysis of the association between executive functioning and effortful control among adolescents. Standardized coefficients are listed for the full model/the trimmed model that retained only attention and inhibitory indicators (*in italics*). NA = Not Applicable. Model fits: $\chi^2 = 13.51$, $df = 8$, CFI = .96 and RMSEA .07 for the full model; $\chi^2 = 2.52$, $df = 3$, CFI = 1.00 and RMSEA .00 for the trimmed model ($\chi^2 = 10.99$, $df = 5$, $p = .052$). * $p < .05$.

Figure 3.

Summarized modeling fitting results of the latent factor model of associations among the cognitive control factor, competence, and internalizing and externalizing symptomatology among children. DCCS = dimensional change card sort. For each path, standardized coefficients are listed. For clarity of presentation, the following correlations are not shown: DCCS ↔ Number Stroop = .21*; internalizing symptomatology ↔ externalizing symptomatology = .42*; inhibitory control ↔ externalizing symptomatology = −.32*; and attention ↔ internalizing symptomatology = −.26*. * $p < .05$.

Figure 4.

Summarized modeling fitting results of the latent factor model of associations among the cognitive control factor, competence, and internalizing and externalizing symptomatology among adolescents. MSIT = Multi-Source interference task; WCST = Wisconsin Card Sort Task. For each path, standardized coefficients are listed. For clarity of presentation, the following residual correlations are not shown: MSIT ↔ WCST = .21*, internalizing symptomatology ↔ externalizing symptomatology = .42*, inhibitory control ↔ externalizing symptomatology = -.32*, and attention ↔ internalizing symptomatology = -.26*. * $p < .05$.

Table 1

Descriptive Statistics for Executive Functioning, Effortful Control, Competence, and Internalizing and Externalizing Symptomatology among Children and Adolescents

	Children			Adolescents		
	<i>M</i>	<i>SD</i>	Range	<i>M</i>	<i>SD</i>	Range
CBQ: Attention Focusing	4.95	0.91	2.17–6.83			
CBQ: Inhibitory Control	4.97	0.94	2.17–7.00			
CBQ: Low Intensity Pleasure	5.82	0.65	3.57–7.00			
CBQ: Perceptual Sensitivity	5.51	0.88	2.00–7.00			
EATQ-R: Attention				3.39	0.62	1.33–4.83
EATQ-R: Inhibitory Control				3.81	0.58	2.20–5.00
EATQ-R: Activation Control				3.16	0.78	1.20–5.00
Digit Span Task	3.07	0.81	0–4.50	5.56	1.75	2–10
Dimensional Change Card Sort	0.68	0.20	0.08–1.00			
Number Stroop	3626.88	1355.50	1637.50–12083.72			
Wisconsin Card Sort Task				7.35	4.14	3.00–32.00
MSIT-Accuracy				–0.10	0.09	–0.63–0.01
MSIT-ISD				0.24	0.03	0.15–0.34
Competence	52.07	11.93	28.00–80.00	41.01	9.13	21.00–61.00
Internalizing Symptomatology	49.36	9.42	33.00–73.00	52.27	10.00	30.00–92.00
Externalizing Symptomatology	50.07	9.95	33.00–75.00	49.81	9.31	9.31

Note. CBQ = Child Behavior Questionnaire short form; EATQ-R = Early Adolescent Temperament Questionnaire –Revised short form; MSIT = Multiple-Source Interference Task; ISD = intraindividual standard deviation.

Table 2

Bivariate Correlations of Executive Functioning, Effortful Control, Competence, and Internalizing and Externalizing 'Symptomatology' among children and adolescents

Variables	1	2	3	4	5	6	7	8	9
Children									
1. CBQ: Attention Focusing	-								
2. CBQ: Inhibitory Control	.57***	-							
3. CBQ: Low Intensity Pleasure	.42***	.42***	-						
4. CBQ: Perceptual Sensitivity	.27***	.51***	.42***	-					
5. Digit Span Task	.16*	.07	.11	.01	-				
6. Dimensional Change Card Sort	.14*	.11	.03	-.12	.23**	-			
7. Number Stroop	.13	.07	.01	-.01	.21**	.15*	-		
8. Competence	.30***	.27***	.17*	.09	.25***	.07	.26***	-	
9. Internalizing Symptomatology	-.16*	-.18**	-.14*	-.08	-.01	.10	-.20**	-.14*	-
10. Externalizing Symptomatology	-.38***	-.55***	-.20**	-.13	.03	-.01	-.08	-.12	.48***
Adolescents									
1. EATQ-R Attention	-								
2. EATQ-R: Inhibitory Control	.40***	-							
3. EATQ-R: Activation Control	.58**	.50***	-						
4. Digit Span Task	.18*	.04	.09	-					
5. Wisconsin Card Sort Task	.22**	.14	.08	.17*	-				
6. MSIT	.13	.21**	.07	.29***	.27**	-			
7. Competence	.07	.09	.13	.02	.19*	.15	-		
8. Internalizing Symptomatology	-.30***	-.16*	-.13	-.02	.03	.11	.02	-	
9. Externalizing Symptomatology	-.27**	-.50***	-.38***	-.04	-.04	-.05	-.06	.46***	-

Note. CBQ = Child Behavior Questionnaire short form; EATQ-R = Early Adolescent Temperament Questionnaire -Revised short form.