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# Household chaos as a context for intergenerational transmission of executive functioning

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## Abstract

Executive functioning (EF) may be transmitted across generations such that strengths or deficiencies in parent EF are similarly manifested in the child. The present study examined the contributions of parent EF and impulsivity on adolescent EF, and investigated whether household chaos is an environmental moderator that alters these transmission processes. American adolescents (N = 167, 47% female, 13–14 years old at Time 1) completed behavioral measures of EF and reported household chaos at Time 1 and one year later at Time 2. Parents completed behavioral measures of EF and self-reported impulsivity at Time 1. Results indicated that lower parent EF at Time 1 predicted lower adolescent EF at Time 2 (controlling for adolescent EF and IQ at Time 1), but only in the context of high household chaos. Findings suggest that household chaos may be a risk factor that compounds influences of poor parent EF and compromises adolescent EF development.

### Keywords

intergenerational transmission; executive functioning; household chaos; impulsivity

Executive functioning (EF) is best understood as a set of higher-order cognitive abilities and self-regulatory processes that includes three distinct but correlated factors: inhibitory control, working memory, and cognitive flexibility (Miyake et al., 2000). These functions work together to guide goal-directed behaviors and are predictive of a number of social

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(Holmes, Kim-Spoon, & Deater-Deckard, 2016), academic (Becker, Miao, Duncan, & McClelland, 2014), and psychological (Letkiewicz et al., 2014; Li, 2015) outcomes. Research has demonstrated that individual differences in EF emerge throughout childhood and adolescence as a function of genetic and environmental conditions, and that EF is transmitted across generations such that strengths or deficiencies in parent EF are similarly manifested in the child (Deater-Deckard, 2014). However, it remains unclear how specific environmental contexts may influence the strength of these effects. It is especially important to understand these processes in adolescence, as EF begins to stabilize during this developmental period (Friedman et al., 2016). In addition to EF, parents' impulsivity may contribute to adolescents' self-regulation development. Behavioral impulsivity is closely related to EF abilities, and impulsive parents may engage in maladaptive parenting styles (Chen & Johnston, 2007) that can further impact adolescent EF outcomes. Thus, the current study sought to understand the contributions of parent indicators of EF and impulsivity to adolescent EF development, and the role of household chaos as an environmental context that may moderate parental influences on EF.

## Intergenerational Transmission of Executive Functioning

Previous research demonstrates that EF similarity between parent and child may manifest as early as 24 months of age, suggesting that transmission of EF is initiated in early childhood (Cuevas, Deater-Deckard, Kim-Spoon, Wang, et al., 2014). As children transition through early and middle childhood, familial similarity in EF increases (Deater-Deckard & Wang, 2012). Once children enter adolescence, EF begins to stabilize; however, there remains little research on *transmission* of EF in adolescence. One exception is a study by Jester et al. (2009), which found moderate to high effect sizes of EF transmission in adolescence ($b^*$ = .34 for fathers and .51 for mothers), similar to what has been found in early childhood (Cuevas et al., 2014). This finding offers preliminary evidence that intergenerational similarity in EF persists into adolescence.

Previous research lends support to the genetic basis of EF abilities. Specifically, moderate heritability has been demonstrated for performance on individual EF tasks (Lee et al., 2012; Vasilopoulos et al., 2012). These individual tasks represent separate EF domains (set-shifting, working memory, and inhibitory control) which are correlated (Miyake et al., 2000), although performance-based indicators of these domains often demonstrate weak intercorrelations (Willoughby et al., 2014). Nonetheless, latent variables of the common EF factor based on the three EF domains demonstrate high heritability, and individual differences in EF are attributable to these genetic influences (Friedman et al., 2016). Importantly, research also demonstrates the importance of the gene and environment interplay which *together* confer individual differences in EF (for a review, see Deater-Deckard, 2014). Thus, in order to fully understand the nature of intergenerational transmission of EF, it is important to consider the different environmental contexts that may affect EF development.

## Environmental Context

Familial environmental factors such as socioeconomic status (Hackman, Gallop, Evans, & Farah, 2015) and parent caregiving (Cuevas, Deater-Deckard, Kim-Spoon, Watson, et al., 2014) influence EF outcomes. However, existing research primarily focuses on how environmental factors are directly related to EF ability. Further research is required to understand environmental contexts of transmission that may promote or reduce familial similarity. Furthermore, mechanisms of transmission are increasingly complicated during adolescence since it is a time of dramatic social, neural, and environmental changes (Nelson, Leibenluft, McClure, & Pine, 2005) which may affect the interactions that facilitate intergenerational transmission. Therefore, it is particularly important to consider environmental contexts that may influence the intergenerational transmission of EF in adolescence.

Household chaos is a particular environmental context that may compromise individuals' EF development. Homes that are highly chaotic are characterized by constant noise, activity, and a lack of structure or routine (Wachs & Evans, 2010). Though they are related, household chaos is a distinct construct from socioeconomic status (SES), and has been shown to affect cognitive functioning independently of SES (Hart, Petrill, Deater-Deckard, & Thompson, 2007). Household chaos is directly and indirectly predictive of a host of self-regulation and adjustment outcomes. For example, Vernon-Faegans, Garrett-Peters, and Willoughby (2016) found that household chaos worked through EF to predict behavior regulation problems in early childhood. Similarly, another study utilizing growth mixture modeling found that higher household chaos in middle childhood predicted membership in groups with lower growth in self-control trajectories across middle-to-late childhood above and beyond SES which, in turn, predicted greater risk-taking in adolescence (Holmes, Kahn, Deater-Deckard, & Kim-Spoon, 2017). It seems that the stressful and distracting qualities of such an unpredictable environment may underlie these deficits in cognitive functioning (Boksem, Meijman, & Lorist, 2005). Previous research has demonstrated the association between household chaos and lower parental self-regulation and EF (Bridgett et al., 2013; Deater-Deckard, Chen, Wang, & Bell, 2012). It follows that household chaos may serve as a common environmental risk factor that has the potential to compromise self-regulatory abilities for the family as a whole, augmenting familial similarity in EF.

Preliminary evidence suggests that the level of chaos in a home may modulate parental influences on child outcomes. For example, household chaos has been shown to moderate the association between parenting and child behavior, such that the association between negative parenting and child behavior problems is stronger for families in a highly chaotic home environment (Asbury et al., 2016; Coldwell, Pike, & Dunn, 2006). Thus, it seems that higher levels of chaos may exacerbate the detrimental effects of negative parenting. However, it has yet to be examined how other parental risk factors, such as poor EF or impulsivity, may influence child outcomes in the context of household chaos.

## Parent Impulsivity

The theoretical perspective on the intergenerational transmission of EF proposed by Deater-Deckard (2014) explains that EF is transmitted across generations within parent-child relationships that provide powerful socialization and further emphasizes how parental reactivity (e.g., impulsivity) and regulation (e.g., EF) interface with each other to influence their offspring's EF development. Indeed, this perspective is consistent with the literature on self-regulation and emphasizes the *regulatory* balance of activation in two distinct neural systems: the impulsive system which consists of portions of the limbic and paralimbic areas that govern impulsivity, and the executive system which consists of the prefrontal cortices that govern EF (Bickel et al., 2007). Impulsivity is closely tied to EF abilities and is best understood as spontaneous, unplanned reactivity to environmental cues that lead to undesirable outcomes (Evenden, 1999). Self-reported impulsivity is a significant predictor of EF such that higher impulsiveness is associated with lower EF (Fino et al., 2014).

Such uninhibited behaviors may have particularly negative ramifications in a family context. For example, impulsive tendencies may manifest as parenting practices that are characterized by inconsistency, impatience, overreactivity, or less use of positive reinforcement (Chen & Johnston, 2007; Harvey et al., 2003). Researchers have not yet examined how the regulatory balance between parents' impulsivity and EF may affect child outcomes, including their development of EF. Accordingly, we explored the possibility that parents' EF and impulsivity independently contribute to adolescent EF.

## The Current Study

The current longitudinal study aimed to examine how the interplay of a common environmental context known to be crucial to self-regulation development and parents' self-regulatory abilities confers intergenerational transmission of EF over time. We hypothesized that parent EF and parent impulsivity at Time 1 would each predict adolescent EF at Time 2, after controlling for baseline levels of adolescent EF at Time 1. Specifically, we expected that lower parent EF and higher parent impulsivity would predict lower adolescent EF. Furthermore, we hypothesized that household chaos would moderate these associations, such that the adverse effects of low parent EF and high parent impulsivity on adolescent EF would be amplified in the context of high household chaos. We statistically controlled for general cognitive ability, given that previous research demonstrates the significant association between intelligence test performance and EF performance (e.g., Jester et al., 2009).

## Method

### Participants

The current sample included 167 adolescents (53% males, 47% females) and their primary caregiver (82% biological mothers, 13% biological fathers, 2% grandmothers, 1% foster, 2% other). Analyses that excluded non-biological caregivers yielded results that were highly consistent with those who we report below, so all dyads (regardless of biological status) were included to maximize statistical power. Adolescents were 13 or 14 years of age at Time

1 (*M* = 14.13, *SD* = 0.54) and 14 or 15 years of age one year later at Time 2 (*M* = 15.05, *SD* = 0.54). Adolescents primarily identified as Caucasian (80%), 13% African-American, and 7% other. Caregivers also primarily identified as Caucasian (88%), 10% African American, and 2% other. Caregiver ages ranged from 31 to 61 years (*M* = 42.02, *SD* = 6.63). The sample was representative of the region of the state for household income and race/ethnicity. For the city and counties sampled, 2010 US Census data showed median annual household income to be in the $36,000–59,000 range, and in the current sample, median household income was in the $35,000-$50,000 range (United States Census Bureau, 2010). At Time 1, 157 adolescent-caregiver dyads participated. However, 17 families did not return at Time 2 (approximately one year later) for reasons including: ineligibility for tasks ($n = 2$), declined participation ($n = 7$), and lost contact ($n = 8$). At Time 2, 10 adolescent-parent dyads were added for a final sample of 167 dyads. Multiple logistic regression analyses indicated that the 17 families who did not return for Time 2 were not significantly different on demographic or model variables from the 140 who did return ($p = .95$ for age, $p = .71$ for income, $p = .76$ for sex, $p = .79$ for race, contrasted as White vs Non-White, $p = .77$ for household chaos, $p = .44$ for parent impulsivity, $p = .42$ for parent EF, $p = .35$ for adolescent EF Time 1, $p = .37$ for adolescent intelligence).

## Measures

**Executive functioning—**EF factor scores were based on confirmatory factor analysis (CFA) of three behavioral tasks that capture the underlying constructs of EF, according to the theoretical model proposed by Miyake and colleagues (2000): working memory, set-shifting, and inhibitory control. EF was measured at both Time 1 and Time 2 for parents and adolescents. Working memory was measured with the Stanford-Binet memory for digits (Roid, 2003) in which participants were asked to repeat back a series of numbers read by the experimenter (first forward, then backwards). An age standardized composite score for combined forward and backward digit-span was calculated and used in the EF factor score. The set-shifting component of EF was captured with the Wisconsin Card Sorting Test (WCST; Heaton, & Staff, 2003) which requires participants to sort a series of cards based on color, number, and shapes of the patterns on the card under changing schedules of reinforcement. Based on their proportion of intentional correct responses, participants received a score for conceptual level which was used in the EF factor score. Finally, inhibitory control was assessed with the Multi-Source Interference Task (MSIT; Bush, Shin, Holmes, Rosen, & Vogt, 2003) in which participants responded to a “different” target number that was either paired with zeroes (neutral condition) or ones, twos, or threes (interference condition). Intra-individual standard deviation (ISD) of reaction time (MacDonald, Karlsson, Rieckmann, Nyberg, & Bäckman, 2012) was calculated for use in the EF factor score, such that lower ISD reaction time reflects better inhibitory control.

**Impulsivity—**Parents’ impulsivity at Time 1 was assessed with the Barratt Impulsiveness Scale short form (BIS-15; Patton, Stanford, & Barratt, 1995). The short form is highly correlated with the full 30 item version (Spinella, 2007) and consists of 15 items capturing the personality trait of impulsiveness. Items are answered on a 4-point scale from “1 = rarely or never” to “4 = almost always or always” with higher scores indicating more impulsivity.

Sample items include "I plan tasks carefully" and "I say things without thinking". The scale demonstrates reliability within the current sample at $\alpha = .88$.

**Household chaos—**Levels of household chaos were measured with adolescent reports on the Confusion, Hubbub, and Order Scale (CHAOS; Matheny, Wachs, Ludwig, & Phillips, 1995). The scale consists of 6 statements about the individuals' home environment. Responses are given on a 5-point Likert scale from "1 = definitely untrue" to "5 = definitely true" with higher scores indicating higher levels of chaos. Sample items include "We are usually able to stay on top of things" and "You can't hear yourself think in our home." Mean scores were calculated for adolescent reports between Time 1 and Time 2. The scale demonstrates relatively low reliability within the current sample at $\alpha = .59$ at Time 1 and .64 at Time 2, consistent with previous research (Coldwell et al., 2006; Pike, Iervolino, Eley, Price, & Plomin, 2006).

**Intelligence—**Adolescents' intelligence was assessed at Time 1 with the Kaufman Brief Intelligence Test ($2^{nd}$ Edition, KBIT; Kaufman & Kaufman, 2004). The KBIT is a short intelligence test appropriate for both adults and children. We specifically tested for verbal intelligence using the Verbal Knowledge and Riddles subscales. Based on the standardized scores of these two scales, we calculated a composite variable of verbal intelligence for adolescents, with higher scores indicating higher intelligence.

## Procedures

Adolescent participants and their parents were recruited as part of a longitudinal study via email announcements, flyers, notices on the internet, or snowball sampling (word-of-mouth). The current study used data from Time 1 (beginning January of 2014) and approximately one year later at Time 2. Data collection took place at the university's offices where adolescents and their primary caregivers were interviewed by trained research assistants. Both parents and adolescents received monetary compensation for their time. All procedures were approved by the institutional review board of the university.

## Plan of Analysis

For all study variables, descriptive statistics were examined to determine normality of distributions and outliers. Skewness and kurtosis were examined for all variable distributions and acceptable levels were less than 3 and 10, respectively (Kline, 2005). Outliers were identified as values ≥ 3 SD from the mean. In these cases ($n = 3$), values were winsorized to retain statistical power and attenuate bias resulting from elimination (Ghosh & Vogt, 2012). Univariate general linear modeling (GLM) analyses exhibited that demographic variables at Time 1 were not significant predictors of adolescent EF outcome at Time 2, thus they were not included as covariates in the main analyses ($p = .17$ for adolescent age, $p = .77$ for family income, $p = .81$ for adolescent sex, $p = .88$ for adolescent race, contrasted as White vs. non-White). Intelligence was entered as a covariate to control for its significant contributions to EF ($p < .001$). The hypothesized models were tested via Structural Equation Modeling (SEM) in MPlus statistical software version 7.2 (Muthén & Muthén, 2009). Overall model fit indices were determined by $\chi^2$ value, degrees of freedom, corresponding $p$-value, Root Mean Square Error of Approximation (RMSEA), and Confirmatory Fit Index

(CFI). RMSEA values of less than .05 were considered a close fit while values less than .08 were considered a reasonable fit (Browne & Cudeck, 1993), and CFI values of greater than .90 were considered an acceptable fit while values greater than .95 were considered an excellent fit (Bentler, 1990). Full information maximum likelihood (FIML) estimation procedure (Arbuckle, 1996) was used for missing data since FIML estimates are superior to those obtained with listwise deletion or other ad hoc methods (Schafer & Graham, 2002).

## Results

### Preliminary Analyses: Measurement Invariance of Executive Functioning

Descriptive statistics and correlations of all model variables are presented in Table 1. Descriptive statistics and correlations of EF components for parents and adolescents are presented in Table 2. We aimed to test factorial invariance for adolescent EF across Time 1 and Time 2 using longitudinal confirmatory factor analysis (CFA). However, the model was not interpretable due to problems with linear dependency. Thus, we examined the factor structure of adolescent EF at Time 1 and Time 2 separately. In these models, all parameters were free to be estimated, yielding a saturated model ($\chi^2 = 0$ and $df = 0$). The factor loadings for indicators across Time 1 and Time 2 were comparable (.55 and .67 for inhibitory control at Time 1 and Time 2, respectively; .39 and .34 for working memory at Time 1 and Time 2, respectively; and .51 and .41 for set-shifting at Time 1 and Time 2, respectively, all $p$s < .05).

### Testing the Moderation Model with Longitudinal Data

Results for the two-group moderation models are presented in Table 3. We formed low chaos (below mean of chaos scores, $n = 91$) versus high chaos (above mean, $n = 76$) groups based on adolescent-reported chaos composite scores. The low/high chaos groups were formed for testing moderating effects of *quantitative* differences in chaos using multiple group SEM; they may not represent *qualitatively* different sub-groups. The initial model included all possible regression paths and covariances and thus was fully saturated. Nonsignificant covariances that were not central to the current study's hypotheses (i.e., covariance between Time 1 parent impulsivity and Time 1 parent EF and covariance between Time 1 parent impulsivity and Time 1 adolescent EF) were then trimmed, as recommended by Little (2013) in order to promote accuracy in estimating hypothesized models.

We compared two nested models to the configural invariance model in which all the parameters were freed to be estimated between the two groups. In the two nested models, we imposed an equality constraint to test numeric invariance between the low and high chaos groups with respect to the effects of parent EF and impulsivity on adolescent EF. The equality constraints were added on one path at a time. In the equal parent impulsivity effect model, the regression paths for parent impulsivity at Time 1 on adolescent EF at Time 2 were constrained to be equal between the low and high chaos group. Then, the equal parent EF model tested the equality regarding the effect of parent EF at Time 1 on adolescent EF at Time 2 between the two groups. In all models, adolescent EF at Time 2 was regressed on adolescent EF at Time 1 and adolescent verbal intelligence to control for the baseline levels of adolescent EF and intelligence. In the nested model comparisons, if the model fit was significantly degraded by imposing equality constraints on particular parameters, the results indicated that the two groups significantly differed with respect to those parameters.

As shown in Table 3, Wald's test of parameter constraints indicated that imposing the equality constraint on the parent impulsivity effect did not significantly degrade model fit, suggesting that the two groups did not differ with respect to the effects of parent impulsivity (Wald $\chi^2 = 0.18$, $df = 1$, $p = .67$). However, imposing the equality constraint on the parent EF effect degraded the model fit significantly, suggesting that the effect of parent EF on adolescent EF differed significantly between the low vs. high chaos groups (Wald $\chi^2 = 3.69$, $df = 1$, $p = .05$). Figure 1 presents the standardized estimates for the final (best-fitting) model in which the regression paths from parent EF to adolescent EF were freed to vary between the two groups, whereas the regression paths from parent impulsivity to adolescent EF were equalized. In this final model, parent EF was significantly related to adolescent EF for the high chaos group ($b = .25$, SE = .11, $p = .03$), whereas parent EF was not related to adolescent EF for the low chaos group ($b = -.03$, $SE = .09$, $p = .73$). Parent impulsivity did not significantly predict adolescent EF in the low chaos group or the high chaos group ($b = -.06$, $SE = .06$, $p = .34$ for both groups).

It is possible that the stronger prediction of parental EF in the high chaos context versus the low chaos context could be due in part to the fact that the high chaos group had greater variability than the low chaos group. Therefore, as supplemental analyses, we tested for equality of variance between the high and low chaos groups based on Wald's chi square difference tests. Specifically, we constrained the variances to be equal between groups for EF variables, one at a time. Wald's test was not significant for parent EF (Wald $\chi^2 = .73$, $df = 1$, $p = .39$), adolescent EF at Time 1 (Wald $\chi^2 = 2.09$, $df = 1$, $p = .22$), or adolescent EF at Time 2 (Wald $\chi^2 = .001$, $df = 1$, $p = .97$) indicating that the groups did not demonstrate significantly different variances. Additionally, using the same procedure we tested equality of means on EF between the low and high chaos groups. Wald's tests indicated that means for adolescent EF at Time 1 (Wald $\chi^2 = .48$, $df = 1$, $p = .49$) and Time 2 (Wald $\chi^2 = 1.24$, $df = 1$, $p = .27$) were not significantly different between groups. Parent EF was significantly lower in the high chaos group (Wald $\chi^2 = 4.71$, $df = 1$, $p = .03$).

## Discussion

The current longitudinal study sought to understand the contributions of parent EF and impulsivity to adolescent EF development. Furthermore, we aimed to identify household chaos as an environmental context for the intergenerational transmission of EF. The results partially supported our hypotheses regarding the moderating roles of household chaos in linking parental risk factors with adolescent EF development. As expected, parent EF significantly predicted longitudinal changes in adolescent EF. Furthermore, this association was contingent on levels of household chaos, such that stronger familial similarity was observed in environments with higher levels of chaos. However, parent impulsivity did not significantly contribute to adolescent EF outcomes. Our findings suggest that household chaos is an environmental context that enhances or attenuates transmission. Above and beyond our current understanding of how environmental contexts may directly impact EF, the present findings offer novel insights regarding developmental processes of EF transmission.

Additionally, our findings extend previous work on EF transmission (Cuevas et al., 2014; Jester et al., 2009) by elucidating the nature of EF transmission from parent to child. To our knowledge, Jester et al. (2009) is the only work available on intergenerational transmission of EF in adolescence. We note that Jester and colleagues reported greater effects of maternal and paternal EF on adolescent EF, though there are several key differences between their study and the current study. First, our longitudinal analysis indicated that parent EF significantly predicted later adolescent EF over one year, even after controlling for baseline levels of adolescent EF. In contrast, Jester and colleagues performed a cross-sectional analysis, although about half of their sample had EF scores combined over two waves (at age 12–14 years and at age 15–17 years). Additionally, we evaluated the effects of parent EF on adolescent EF after controlling for the contribution by adolescents' own IQ, whereas Jester and colleagues controlled for parents' IQ. Most importantly, in addition to presenting evidence for longitudinal transmission of EF, the current findings highlighted that the occurrence of intergenerational transmission may be dependent on family environmental contexts.

Current theories suggest that development and intergenerational transmission of EF and other aspects of self-regulation are guided by multiple levels of contributions including biological and environmental contributions (Bridgett, Burt, Edwards, & Deater-Deckard, 2015). Our finding of transactional processes through which parent EF and household environment work together to contribute to EF development illustrates the multiple levels of influence through which EF may be affected. As described in a review by Deater-Deckard (2014), intergenerational transmission of self-regulatory processes occurs through combinations of multiple levels of effects—including genetic, social, and broader family and home contexts—which work together to confer individual differences. Thus, EF may be more uniform between parent and child in high chaos homes because, in addition to biological mechanisms of transmission, there is also a *salient* common home environment.

The nature of a highly chaotic home may have a substantial and pervasive effect on the entire family that fosters homogeneity in EF. This effect may particularly be a function of the distracting and uncontrollable nature of highly chaotic homes, which may undermine and interrupt parents' exercise of self-regulation skills and children's development of self-regulation abilities (Wachs & Evans, 2010). In low chaos environments, EF may be less uniform between parent and child because while there is still biological transmission, chaos does not serve as a salient, influential environmental context that compounds other transmission mechanisms. Since intergenerational transmission works through multiple mechanisms, if one mechanism is not especially salient (in this case, home environment), transmission may not be as robust as it is in more impactful environments. Taken together, the results suggest that environmental chaos may exacerbate pre-existing biological risk for sub-optimal EF development.

This pattern of results reflects the vulnerable-reactive model of risk and resilience proposed by Luthar, Cicchetti, and Becker (2000). The model posits that a disadvantage or vulnerability has pronounced effects on competence outcomes in the context of a certain attribute. Applied to our findings, the disadvantage of low parent EF is transmitted to the adolescent thereby compromising EF development, when compounded by high household chaos. In this way, household chaos serves as an environmental attribute that enhances the pre-existing vulnerability for maladaptive EF development. These findings are further supported by previous research that has identified an association between high household chaos and low parent EF (Deater-Deckard et al., 2012). Indeed, our data suggest that high household chaos was likely to accompany low parent EF (as shown by the significant group difference in parent EF), and the two vulnerability factors contributed to lower adolescent EF.

Our hypotheses regarding the contributions of parent impulsivity were not supported in the current study. Based on existing theoretical perspectives on intergenerational transmission of EF (Deater-Deckard, 2014), we tested the roles of parent reactivity (i.e., impulsivity) and EF in the development of adolescent EF outcomes. However, regardless of household chaos levels, parent impulsivity was not related to adolescent EF. It is possible that this disconnect is explained by genetic dominance effects. Impulsivity is highly heritable (Fineberg et al., 2014) and is associated with EF. Because of this, we expected higher parent impulsivity to significantly predict adolescent EF. However, previous work demonstrates that most of the genetic variance of impulsivity is non-additive (Mullineaux, Deater-Deckard, Petrill, Thompson, & DeThorne, 2009), and thus may obscure any similarity between the parent and child. Methodologically, it is possible that the non-significant effect of parent impulsivity is due to the difference in modalities of measurement for each of these constructs. Specifically, impulsivity was assessed with self-report, whereas EF was based on performance on behavioral tasks. This measurement discrepancy may have attenuated effects that parent impulsivity might have on adolescent EF development. Relatedly, self-report of impulsivity may not necessarily reflect behavioral impulsivity. It is possible that the lack of relationship between parent impulsivity and adolescent EF may be related to this measurement limitation. Future work should consider behavioral indicators of impulsivity that we were not able to test in the current study.

Findings from the current study should be interpreted in the context of study limitations. First, the results are representative of a predominantly White sample and thus await further replication to be generalized to populations with greater racial diversity. Second, in terms of analytic strategy, we used a dichotomized score to represent household chaos (i.e., high vs low). In this way, we simplified variance in chaos scores in our sample. However, using the multiple group SEM approach allowed us to test systematically where the significant moderation effects of chaos become statistically significant by imposing an equality constraint on one path at a time while testing statistical significance in changes in model fits (using a chi-square difference test). Third, we acknowledge that the use of factor scores lends itself to potential issues of factor indeterminacy. Though we had strong theoretical basis for the EF factors, future work that measures EF using factor scores should employ them cautiously, acknowledging the potential bias that can result from highly indeterminate factors (Grice, 2001). Finally, while biological transmission is inferred from the genetic relationship between the parent and adolescent, genetic data were not available in the current analyses. Future research would benefit from considering genetic information to better understand gene by environment interaction effects in the development of EF. Further research should also identify whether adolescent EF abilities begin to differentiate from their parents' in later periods of development (beyond early adolescence as observed in the current study), since adolescent development is increasingly influenced by sources outside of the immediate family context over time (Glynn, 1981).

Despite these limitations, the current study enhances our understanding of the underlying mechanisms that strengthen similarity between parent and adolescent EF. The use of multiple measures to capture the latent construct of EF lends credence to our findings. Given the importance of EF in the prediction of a host of outcomes including externalizing psychopathology and academic success, it is especially important to elucidate the underlying mechanisms of EF development. The concerns regarding increased similarity between low parental EF and low adolescent EF are particularly germane to families whose EF is compromised by chaotic, unpredictable home environments. Fostering an environment that is more structured and tranquil may weaken detrimental influences of poor parent EF on children's EF development. Research has demonstrated that family-centered prevention efforts can ameliorate children's self-regulation outcomes (Brody et al., 2005; Fosco et al., 2013); the current findings suggest that intervention efforts that also address household chaos may be particularly efficacious. Future research should attempt to identify additional environmental or familial contingencies that may positively alter EF transmission.

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## References

Aiken, LS., West, SG. Multiple regression: Testing and interpreting interactions. Thousand Oaks: Sage Publications Inc; 1991.

Arbuckle, JL. Full information estimation in the presence of incomplete data. In: Marcoulides, GA., Schumacker, RE., editors. Advanced structural equation modeling: Issues, techniques. Mahwah, NJ: Erlbaum; 1996. p. 243-277.

Asbury K, Dunn JF, Pike A, Plomin R. Nonshared environmental influences on individual differences in early behavioral development: A monozygotic twin differences study. Child Development. 2016; 74:933–943.

Becker DR, Miao A, Duncan R, McClelland MM. Behavioral self-regulation and executive function both predict visuomotor skills and early academic achievement. Early Childhood Research Quarterly. 2014; 29:411–424.

Bentler PM. Comparative fit indexes in structural models. Psychological Bulletin. 1990; 107:238–246. [PubMed: 2320703]

Bickel WK, Miller ML, Yi R, Kowal BP, Lindquist DM, Pitcock JA. Behavioral and neuroeconomics of drug addiction: Competing neural systems and temporal discounting processes. Drug and Alcohol Dependence. 2007; 90:S85–S91. [PubMed: 17101239]

Boksem MAS, Meijman TF, Lorist MM. Mental fatigue, motivation and action monitoring. Biological Psychology. 2006; 72:123–132. http://doi.org/10.1016/j.biopsycho.2005.08.007. [PubMed: 16288951]

Bridgett DJ, Burt NM, Edwards ES, Deater-Deckard K. Intergenerational transmission of self-regulation: A multidisciplinary review and integrative conceptual framework. Psychological Bulletin. 2015; 141:602–654. http://doi.org/10.1037/a0038662. [PubMed: 25938878]

Bridgett DJ, Burt NM, Laake LM, Oddi KB. Maternal self-regulation, relationship adjustment, and home chaos: Contributions to infant negative emotionality. Infant Behavior and Development. 2013; 36:543–547. http://doi.org/10.1016/j.infbeh.2013.04.004.

Brody GH, McBride Murry V, McNair L, Chen YF, Gibbons FX, Gerrard M, Ashby Wills T. Linking changes in parenting to parent-child relationship quality and youth self-control: The Strong African American Families Program. Journal of Research on Adolescence. 2005; 15:47–69.

Bush G, Shin LM, Holmes J, Rosen BR, Vogt BA. The Multi-Source Interference Task: Validation study with fMRI in individual subjects. Molecular Psychiatry. 2003; 8:60–70. [PubMed: 12556909]

Chen M, Johnston C. Maternal inattention and impulsivity and parenting behaviors. Journal of Clinical Child and Adolescent Psychology. 2007; 36:455–468. [PubMed: 17658988]

Coldwell J, Pike A, Dunn J. Household chaos–links with parenting and child behaviour. J. Child Psychol. Psyc. 2006; 47:1116–1122.

Cuevas K, Deater-Deckard K, Kim-Spoon J, Wang Z, Morasch KC, Bell MA. A longitudinal intergenerational analysis of executive functions during early childhood. British Journal of Developmental Psychology. 2014; 32:50–64. http://doi.org/10.1111/bjdp.12021. [PubMed: 25284715]

Cuevas K, Deater-Deckard K, Kim-Spoon J, Watson AJ, Morasch KC, Bell MA. What's mom got to do with it? Contributions of maternal executive function and caregiving to the development of executive function across early childhood. Developmental Science. 2014; 17:224–238. http://doi.org/10.1111/desc.12073. [PubMed: 24410963]

Deater-Deckard K. Family matters: Intergenerational and interpersonal processes of executive function and attentive behavior. Current Directions in Psychological Science. 2014; 23:230–236. http://doi.org/10.1177/0963721414531597. [PubMed: 25197171]

Deater-Deckard K, Chen N, Wang Z, Bell MA. Socioeconomic risk moderates the link between household chaos and maternal executive function. Journal of Family Psychology. 2012; 26:391–399. http://doi.org/10.1037/a0028331. [PubMed: 22563703]

Deater-Deckard, K., Wang, Z. Development of temperament and attention: Behavioral genetic approaches. In: Posner, M., editor. Cognitive neuroscience of attention. 2. New York, NY: Guilford; 2012. p. 331-342.(n.d.)

Distefano C, Zhu M, Mîndrilă D. Understanding and using factor scores: Considerations for the applied researcher. Practical Assessment, Research & Evaluation. 2009; 14:1–11.

Evenden JL. Varieties of impulsivity. Psychopharmacology. 1999; 146:348–361. [PubMed: 10550486]

Fineberg, Na, Chamberlain, SR., Goudriaan, AE., Stein, DJ., Vanderschuren, LJMJ., Gillan, CM., Potenza, MN. New developments in human neurocognition: clinical, genetic, and brain imaging correlates of impulsivity and compulsivity; CNS Spectrums. 2014. p. 69-89.http://doi.org/10.1017/S1092852913000801

Fino E, Melogno S, Iliceto P, D'Aliesio S, Pinto MA, Candilera G, Sabatello U. Executive functions, impulsivity, and inhibitory control in adolescents: A structural equation model. Advances in Cognitive Psychology. 2014; 10:32–38. http://doi.org/10.2478/v10053-008-0154-5. [PubMed: 25157298]

Fosco GM, Frank JL, Stormshak EA, Dishion TJ. Opening the "Black Box": Family Check-Up intervention effects on self-regulation that prevents growth in problem behavior and substance use. Journal of School Psychology. 2013; 51:455–468. [PubMed: 23870441]

Friedman NP, Miyake A, Altamirano LJ, Corley RP, Young SE, Rhea SA, Hewitt JK. Stability and change in executive function abilities from late adolescence to early adulthood: A longitudinal twin study. Developmental Psychology. 2016; 52:326–340. http://doi.org/10.1037/dev0000075. [PubMed: 26619323]

Friedman, NP., Miyake, A. Unity and diversity of executive functions: Individual differences as a window on cognitive structure; Cortex. 2016. p. 1-19.http://doi.org/10.1016/j.cortex.2016.04.023

Ghosh, D., Vogt, A. Outliers: An evaluation of methodologies. Pages 3455–3460 in Joint Statistical Meetings. American Statistical Association; San Diego, CA: 2012.

Glynn TJ. From family to peer: A review of transitions of influence among drug-using youth. Journal of Youth and Adolescence. 1981; 10:363–383. [PubMed: 24310489]

Hackman DA, Gallop R, Evans GW, Farah MJ. Socioeconomic status and executive function: Developmental trajectories and mediation. Developmental Science. 2015; 18:686–702. http://doi.org/10.1111/desc.12246. [PubMed: 25659838]

Harvey E, Danforth JS, Eberhardt McKee T, Ulaszek WR, Friedman JL. Parenting of children with Attention-Deficit/Hyperactivity Disorder (ADHD): The role of parental ADHD symptomatology. Journal of Attention Disorders. 2003; 7:31–42. http://doi.org/10.1177/108705470300700104. [PubMed: 14738179]

Hart SA, Petrill SA, Deckard KD, Thompson LA. SES and CHAOS as environmental mediators of cognitive ability: A longitudinal genetic analysis. Intelligence. 2007; 35:233–242. [PubMed: 19319205]

Heaton, RK., Staff, PAR. Wisconsin card sorting test: Computer version 4-research edition (WCST: CV4). Lutz, FL: Psychological Assessment Resources; 2003.

Holmes, Kahn, Deater-Deckard, Kim-Spoon. Family environment effects on developmental trajectories of self-control and adolescent risk taking. Manuscript under review. 2017

Holmes CJ, Kim-Spoon J, Deater-Deckard K. Linking executive function and peer problems from early childhood through middle adolescence. Journal of Abnormal Child Psychology. 2016; 44:31–42. http://doi.org/10.1007/s10802-015-0044-5. [PubMed: 26096194]

Jester JM, Nigg JT, Puttler LI, Long JC, Fitzgerald HE, Zucker RA. Intergenerational transmission of neuropsychological executive functioning. Brain and Cognition. 2009; 70:145–153. http://doi.org/10.1016/j.bandc.2009.01.005. [PubMed: 19243871]

Kaufman, AS., Kaufman, NL. Kaufman Brief Intelligence Test. Second. Bloomington, MN: Pearson, Inc; 2004.

Kline, RB. Principles and practice of structural equation modeling. 3. New York: Guildford Press; 2011.

Lee T, Mosing MA, Henry JD, Trollor JN, Ames D, Martin NG, Sachdev PS. Genetic influences on four measures of executive functions and their covariation with general cognitive ability: The Older Australian Twins Study. Behavior Genetics. 2012; 42:528–538. http://doi.org/10.1007/s10519-012-9526-1. [PubMed: 22302529]

Letkiewicz, AM., Miller, GA., Crocker, LD., Warren, SL., Infantolino, ZP., Mimnaugh, KJ., Heller, W. Executive function deficits in daily life prospectively predict increases in depressive symptoms; Cognitive Therapy and Research. 2014. p. 612-620.http://doi.org/10.1007/s10608-014-9629-5

Little, TD., Card, NA., Bovaird, JA., Preacher, KJ., Crandall, CS. Structural equation modeling of mediation and moderation with contextual factors. In: Little, TD.Bovaird, JA., Card, NA., editors. Modeling contextual effects in longitudinal studies. Mahwah, NJ: Lawrence Erlbaum Associates; 2007. p. 207-230.

Little, TD. Longitudinal Structural Equation Modeling: Methodology in the Social Sciences. New York, NY: The Guilford Press; 2013.

Luthar SS, Cicchetti D, Becker B. The construct of resilience: a critical evaluation and guidelines for future work. Child Development. 2000; 71:543–562. http://doi.org/10.1111/1467-8624.00164. [PubMed: 10953923]

Muthén, LK., Muthén, B. Mplus user's guide [Computer software and manual]. 7. Los Angeles, CA: Author; 2012.

MacDonald SWS, Karlsson S, Rieckmann A, Nyberg L, Bäckman L. Aging-related increases in behavioral variability: Relations to losses in dopamine D1 receptors. Journal of Neuroscience. 2012; 32:8186–8191. [PubMed: 22699899]

Matheny AP, Wachs TD, Ludwig JL, Phillips K. Bringing order out of chaos: Psychometric characteristics of the Confusion, Hubbub, and Order Scale. Journal of Applied Developmental Psychology. 1995; 16:429–444.

Meule A, Mayerhofer M, Gründel T, Berker J, Teran CB, Platte P. Half-year retest-reliability of the Barratt Impulsiveness Scale–Short form (BIS-15). SAGE Open. 2015; 5

Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A, Wager TD. The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. Cognitive Psychology. 2000; 41:49–100. http://doi.org/10.1006/cogp.1999.0734. [PubMed: 10945922]

Mullineaux PY, Deater-Deckard K, Petrill SA, Thompson LA, DeThorne LS. Temperament in middle childhood: A behavioral genetic analysis of fathers' and mothers' reports. Journal of Research in Personality. 2009; 43:737–746. http://doi.org/10.1016/j.jrp.2009.04.008. [PubMed: 20216930]

Nelson EE, Leibenluft E, McClure EB, Pine DS. The social re-orientation of adolescence: a neuroscience perspective on the process and its relation to psychopathology. Psychological Medicine. 2005; 35:163–174. http://doi.org/10.1017/S0033291704003915. [PubMed: 15841674]

Patton JH, Stanford MS, Barratt ES. Factor structure of the Barratt Impulsiveness Scale. Journal of Clinical Psychology. 1995; 51:768–774. [PubMed: 8778124]

Pike A, Iervolino AC, Eley TC, Price TS, Plomin R. Environmental risk and young children's cognitive and behavioral development. International Journal of Behavioral Development. 2006; 30:55–66.

Roid, GH. Stanford-Binet Intelligence Scales. Fifth. Itasca, IL: Riverside Publishing; 2003.

Schafer JL, Graham JW. Missing data: Our view of the state of the art. Psychological Methods. 2002; 7:147–177. [PubMed: 12090408]

Shulman EP, Smith AR, Silva K, Icenogle G, Duell N, Chein J, Steinberg L. The dual systems model: Review, reappraisal, and reaffirmation. Developmental Cognitive Neuroscience. 2016; 17:103–117. DOI: http://dx.doi.org/10.1016/j.dcn.2015.12.010. [PubMed: 26774291]

Spinella M. Normative data and a short form of the Barratt Impulsiveness Scale. International Journal of Neuroscience. 2007; 117:359–368. [PubMed: 17365120]

United States Census Bureau. American community survey. 2010. Retrieved from http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t

Vasilopoulos T, Franz CE, Panizzon MS, Xian H, Grant MD, Lyons MJ, Kremen WS. Genetic architecture of the Delis-Kaplan Executive Function System trail making test: Evidence for distinct genetic influences on executive function. Neuropsychology. 2012; 16:387–393. http://doi.org/10.1016/j.cmet.2012.08.002.

Vernon-Feagans L, Willoughby M, Garrett-Peters P. The Family Life Project Key Investigators Predictors of behavioral regulation in kindergarten: Household chaos, parenting and early executive functions. Developmental Psychology. 2016; 52:37–54. http://doi.org/10.1016/bs.mcb.2015.01.016.

Wachs, TD., Evans, GW. Chaos in context. In: Evans, G., Wachs, T., editors. Chaos and its influence on children's development, an ecological perspective. Washington, DC: American Psychological Association; 2010. p. 3-13.http://dx.doi.org/10.1037/12057-001

Willoughby M, Holochwost SJ, Blanton ZE, Blair CB. Executive functions: Formative versus reflective measurement. Measurement: Interdisciplinary Research and Perspectives. 2014; 12:69–95. http://doi.org/10.1080/15366367.2014.929453.

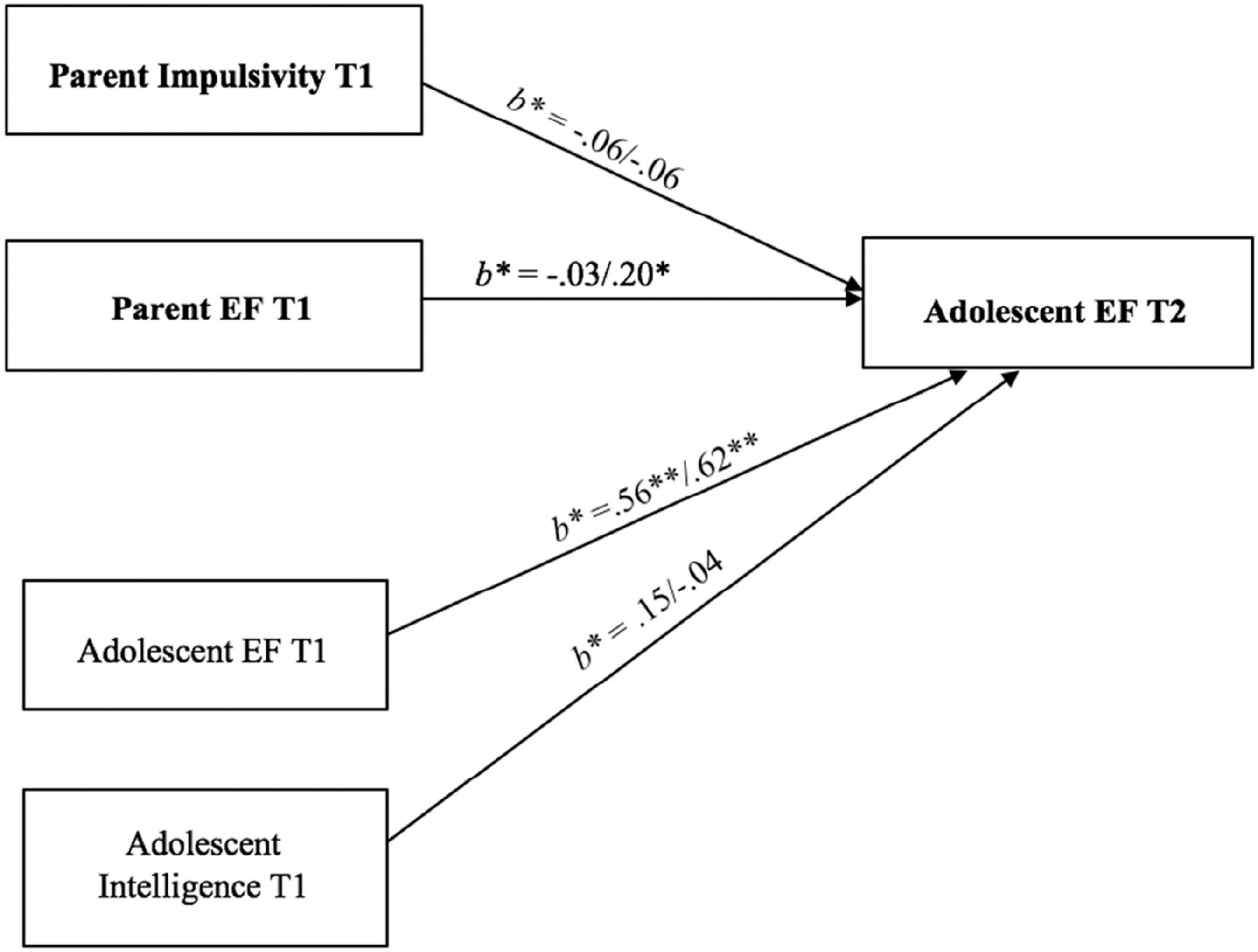


**Figure 1. Path analysis model for the longitudinal effects of parental EF and impulsivity on adolescent EF moderated by household chaos**

*Note*. Standardized parameter estimates are listed for the low chaos group/the high chaos group. Covariances among predictors were estimated, but are not shown in the figure for clarity of presentation (Parent EF T1 <-> adolescent EF T1 = .22/.31, adolescent intelligence <-> adolescent EF T1 = .41/.55, adolescent intelligence <-> parent EF T1 = .23/.23, adolescent intelligence <-> parent impulsivity = −.06/−.22). EF = executive functioning; T1 = Time 1; T2 = Time 2. *$p < .05$; **$p < .001$.

## Table 1

Descriptive statistics and correlations for main study variables

| Variables | 1 | 2 | 3 | 4 | 5 | *M (SD)* | Range |
|---|---|---|---|---|---|---|---|
| 1. Parent Executive Functioning Time 1 | | | | | | 0.00 (.45) | −1.16 – 1.18 |
| 2. Parent Impulsivity Time 1 | −.21** | | | | | 1.99 (.50) | 1.00 – 3.33 |
| 3. Adolescent Executive Functioning Time 1 | .27** | −.06 | | | | 0.00 (.38) | −1.15 – .92 |
| 4. Adolescent Executive Functioning Time 2 | .23** | −.10 | .63** | | | 0.00 (.49) | −1.29 – .97 |
| 5. Household Chaos | −.10 | .13 | −.13 | −.20** | | 2.44 (.63) | 1.17 – 4.33 |
| 6. Adolescent Verbal Intelligence Time 1 | .28** | −.18** | .47** | .38** | −.26** | 106.40 (14.08) | 78.00 – 145.00 |

*Note.* $^{*}p < .05$

$^{**}p < .01$.

## Table 2

Descriptive statistics and correlations for indicators of executive functioning (inhibitory control, working memory, and set-shifting)) among parents and adolescents

| Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | *M (SD)* |
|---|---|---|---|---|---|---|---|---|---|
| **Time 1** | | | | | | | | | |
| 1. Adolescent inhibitory control | | | | | | | | | 1.00 (.04) |
| 2. Adolescent working memory | .21** | | | | | | | | 96.73 (12.75) |
| 3. Adolescent set-shifting | .28** | .20** | | | | | | | 45.98 (10.62) |
| 4. Parent inhibitory control | .28** | .17* | .07 | | | | | | 1.66 (.05) |
| 5. Parent working memory | .22** | .29** | .07 | .44** | | | | | 99.45 (16.03) |
| 6. Parent set-shifting | .08 | .01 | .09 | .17* | .30** | | | | 45.34 (12.71) |
| **Time 2** | | | | | | | | | |
| 7. Adolescent inhibitory control | .49** | .25** | .25** | .17 | .18* | .10 | | | 1.00 (.04) |
| 8. Adolescent working memory | .12 | .67** | .20* | −.01 | .23** | −.02 | .22** | | 99.00 (13.69) |
| 9. Adolescent set-shifting | .29** | .25** | .53** | .20* | .09 | .07 | .27** | .14 | 51.24 (7.05) |

* *Note*. $p < .05$

** $p < .01$.

## Table 3

Model Fit Comparisons for SEM Analyses Testing the Associations among Adolescent Executive Functioning, Parent Impulsivity, and Parent Executive Functioning for High vs. Low Chaos Groups

| **Model Label** | $\chi^2$ | ***df*** | ***p*** | **CFI** | **RMSEA** | **Model Comparison** | **Wald** $\chi^2$ | **Wald *df*** | **Wald *p*** |
|---|---|---|---|---|---|---|---|---|---|
| 1. Configural invariance model | 6.86 | 4 | .14 | .96 | .09 | | | | |
| **2. Equal parent impulsivity model** | **7.04** | **5** | **.22** | **.97** | **.07** | **1 vs 2** | **0.18** | **1** | **.67** |
| 3. Equal parent EF model | 10.68 | 6 | .10 | .93 | .10 | 2 vs 3 | 3.69 | 1 | .05 |

*Note*. CFI = comparative fit index; RMSEA = root mean square error of approximation. Best-fitting model is in bold face.