Abstract

Although the association between deficits in effortful control and later externalizing behavior is well established, many researchers (Nigg, 2006; Steinberg, 2008) have hypothesized this association is actually the product of the *imbalance of dual systems*, or two underlying traits: approach and self-regulation. Very little research, however, has deployed a statistically robust strategy to examine that compelling model; further, no research has done so using behavioral measures, particularly in longitudinal studies. We examined the imbalance of approach and self-regulation (effortful control, EC) as predicting externalizing problems. Latent trait models of approach and EC were derived from behavioral measures collected from 102 children in a community sample at 25, 38, 52, and 67 months (2 to 5 ½ years), and used to predict externalizing behaviors, modeled as a latent trait derived from parent-reported measures at 80, 100, 123, and 147 months (6 ½ to 12 years). The imbalance hypothesis was supported: Children with an imbalance of approach and EC had more externalizing behavior problems in middle childhood and early preadolescence, relative to children with equal levels of the two traits.

Keywords: dual systems, imbalance, effortful control, approach, externalizing

An Imbalance of Approach and Effortful Control Predicts Externalizing Problems: Support for Extending the Dual-Systems into Early Childhood

Externalizing behavior accounts for a significant portion of total health burden and mortality among adolescents (Blum & Nelson-Mmari, 2004; Williams, Holmbeck, & Greenley, 2002). That liability is carried forward into adulthood: By the time they are 28, those who had externalizing problems at age 10 have cost society ten times as much as their peers (Scott, Knapp, Henderson, & Maughan, 2001), and have poor social and health outcomes (Moffitt et al., 2011). The trajectory begins remarkably early. Aggression observed in toddlers and preschool-aged children predicts externalizing behaviors in middle childhood (Shaw et al., 1996), which tends to persist into adolescence (Campbell, Shaw, & Gilliom, 2000; Rowe et al, 2010; Shaw et al., 1996), with a subset of individuals remaining on a long-term disruptive, antisocial trajectory (Moffit, 1993). Because of the burdens associated with externalizing behavior – for the individual, family, and society – basic and translational research on early origins of disruptive, externalizing problems remains a high priority.

Externalizing behavior problems relate closely to deficits in effortful control (EC), a key aspect of children's temperament and personality (Caspi and Shiner, 2006; Derryberry & Rothbart, 1997; Rothbart & Bates, 2006; Sulik, 2017). EC, the capacity to deliberately suppress a dominant response and perform a sub-dominant response (typically, a long-term goal, or a socially desirable behavior) emerges in the second year. Children with robust EC skills embark on a trajectory to an array of desired developmental outcomes, such as internalization of rules (Kochanska & Knaack, 2003), resiliency and robust adjustment (Eisenberg et al., 2004), wealth (Moffitt et al., 2011), and academic success (Rueda, 2012; Valiente, Lemery-Chalfant, Swanson, & Reiser, 2008). By contrast, low EC in early childhood predicts a host of negative psychosocial

outcomes, including externalizing behavior (Hart, Hofmann, Edelstein, & Keller, 1997; Kochanska & Knaack, 2003; Kochanska, Murray, & Harlan, 2000; Krueger, Caspi, Moffitt, White, & Stouthamer-Loeber, 1996; Quinn & Harden, 2013).

Some researchers have distinguished between two forms of EC, "cool" and "hot". Cool EC tasks generally involve inhibiting or shifting cognitive or motor responses, whereas hot EC tasks require inhibiting or delaying a response to an emotionally salient, or "hot" cue, typically a hedonically appealing reward. Hot EC has been most consistently associated with externalizing behavior (Botdorf, Rosenbaum, Patrianakos, Steinberg, & Chein, 2017; Kim, Nordling, Yoon, Boldt, & Kochanska, 2013; Willoughby, Kupersmidt, Voegler-Lee & Bryant, 2011).

Approach, another temperament trait, has also been implicated in the origin of externalizing problems. Approach is one aspect of a broader spectrum of traits that includes surgency, reward orientation, sensation seeking, high-intensity pleasure, and several aspects of positive emotionality (Clark & Watson, 1999; Kochanska, Aksan, Penney & Doobay, 2007; Putnam, 2012; Rothbart & Bates, 2006; Tackett, Martel, & Kushner, 2012). High approach, assessed as early as infancy, has been linked to later aggression (Rothbart, Ahadi, & Hershey, 1994), and at preschool age, to poorer restraint and more rule-breaking behavior (Kochanska et al., 2007). In clinical literature, approach-related traits, such as the Behavioral Activation System (BAS; Gray, 1991), sensitivity to reward, surgency, and extraversion have often predicted adolescent substance abuse, psychopathy, and Attention Deficit Hyperactivity Disorder (Cyders, Flory, Rainer & Smith, 2009; Evans & Rothbart, 2007; Hundt, Kimbrel, Mitchell & Nelson-Gray, 2008; Nigg, 2006).

Recently, several compelling models have proposed that *the interplay* between appetitive, or reward-oriented processes (e.g., approach) and self-regulatory processes (e.g., EC) and may be

key to elucidating origins of externalizing problems (Nigg, 2006). In his *dual-systems model*, Steinberg (2008) integrates approach, EC, and externalizing, although he refers to constructs of sensation seeking, self-regulation (and sometimes impulse control; Icenogle et al., 2017), and risk-taking, respectively. Sensation seeking, an aspect of approach, is driven by developing dopaminergic pathways, and increases from preadolescence through late adolescence, peaking at age 19. The ability to self-regulate (EC), however, lags behind. Areas of the lateral prefrontal cortex, thought to underlie EC, continue developing throughout the mid-20s (Steinberg, 2017). That developmental mismatch, or imbalance, between sensation seeking and EC is theorized to result in risk-taking, a marker of externalizing behavior. Indeed, Steinberg's (2017) recent work provides robust evidence that sensation seeking and self-regulation develop according to the timeline consistent with dual-systems theory, and that the developmental window in which the imbalance occurs is parallel across cultures. Shulman, Harden, Chein, and Steinberg (2016) demonstrate that while sensation seeking and self-control are correlated, they develop independently of one another. Furthermore, a small but growing body of neuroimaging literature supports links among sensation seeking, self-regulation, and risk-taking, consistent with dual-systems theory (for a review, see Shulman et al., 2016).

Steinberg's (2017) compelling model convincingly demonstrates *why* the imbalance between approach and self-regulation (or EC) occurs, and how the mismatched neurodevelopmental trajectories result in externalizing behavior in adolescence. The imbalance hypothesis, however, should apply to other developmental periods as well, particularly if it were reframed in terms of individual differences. The conceptual innovation of the current work is to propose a framework of *individual differences*, inspired by Steinberg's model. We focus on the approach-EC imbalance, conceptualized within the individual differences framework, from the

toddler through kindergarten age, as a predictor of externalizing behavior problems from early school age to preadolescence. Of note, our model is consistent with Rothbart and Bates' (2006) concept of "temperament by temperament" interactions, first introduced and reviewed in their chapter devoted to individual differences.

The pertinent literature on the interplay of *individual differences* in approach and EC as liabilities for externalizing problems is sparse and inconsistent. Cross-sectional studies have investigated associations among approach, EC, and externalizing in adolescents and young and older adults (Gardner & Steinberg, 2005; Steinberg et al., 2008), but these studies cannot inform our understanding of causal pathways. Longitudinal studies (Alloy et al., 2009) found that high BAS and impulsivity predicted substance abuse problems in young adults. Rudolph, Troop-Gordon, and Llewellyn (2013) found that social approach among 9-year-old boys interacted with low inhibitory control and low social avoidance to predict antisocial behavior. Lahat and colleagues (2012) demonstrated that interplay between exuberance in the first three years and executive functioning at age 4 predicted risk taking at age 5. However, a large, cross-national study of approach, EC, and risk-taking (Duell et al., 2016) showed that both approach and EC independently predicted risk-taking, but failed to find a significant interaction.

The inconsistent findings may be due to three methodological issues. One, the potential quadratic effects of approach and EC have been largely ignored; two, few studies have controlled for internalizing problems; and three, few studies have incorporated behavioral measures of approach and EC. In the current article, we address these three gaps using robust analytic and methodological strategies.

First, we estimated the quadratic effects of approach and EC, because un-modeled quadratic terms can manifest as spurious interaction effects. The preponderance of evidence

shows that extreme scores on positive emotionality, negative emotionality, and EC are associated with externalizing and internalizing psychopathology in adults (Clark, Vorhies, & McEwen, 1994; Widiger & Simonsen, 2005; Wiggins & Pincus, 1994) and children and adolescents (Van den Akker et al., 2013). In addition, approach and EC are moderately correlated (r = -0.24 to -0.34; Shulman, Harden, Chien & Steinberg, 2016). When the quadratic effects of two correlated traits are omitted, spurious interaction terms can emerge (Balli & Sørensen, 2012). In other words, even if there is no interaction between approach and EC, un-modelled quadratic effects of either trait (for example, if both high and low approach led to externalizing, consistent with both hyper- and hypo-dopaminergic etiologies of Attention-Deficit Hyperactivity Disorder; Castellanos & Tannock, 2002) could drive a false interaction effect. It is striking that very few studies have tested a quadratic effect of EC (although see Eisenberg et al., 2003; Martel et al., 2007; Murray & Kochanska, 2002; Wang, Chassin, Eisenberg, & Spinrad, 2015). In an important exception, Valiente and colleagues (2013) tested the quadratic effect of impulsivity, as well as the interaction of EC and impulsivity; however, they did not do so in the *same* model. No study has estimated quadratic effects for both approach and EC and their interaction simultaneously, which is the critical test of the imbalance hypothesis (Edwards, 2001).

Second, we accounted for comorbidity of internalizing and externalizing problems, particularly common in children (Lilienfeld, 2003). That comorbidity may complicate the testing of imbalance hypotheses. Woltering, Lishak, Hodgson, Granic, and Zelazo (2016) found significant EC deficits not only in children with externalizing problems, but also in children with comorbid internalizing and externalizing problems. Eisenberg and colleagues (Eisenberg et al., 2009; Wang et al., 2015) found a combination of high impulsivity and low EC in children with *comorbid* internalizing and externalizing problems. Van den Akker, Deković, Asscher, Shiner,

and Prinzie (2013) found that high trait extraversion (linked to approach) and low conscientiousness (linked to EC) predicted both internalizing and externalizing problems. In sum, it appears that children with an imbalance *in either direction* may have some degree of *both* internalizing and externalizing problems. Thus, controlling for comorbid internalizing problems, to test whether the imbalance effect is specific to externalizing behavior, seems prudent.

Third, we assessed approach and EC beginning at toddler age, using robust behavioral measures. All past work focused on adolescence, although stable individual differences in approach emerge in infancy (Hane et al., 2008; Rothbart, 2007), and EC in the second year (Kochanska et al., 2000; Rothbart & Bates, 2006; Rueda, 2012). One exception is Lahat et al., (2012), but they did not follow children past age 5. The current study is, to our knowledge, the first longitudinal investigation of the imbalance hypothesis that captures the interplay of approach and EC in toddlerhood, and explores how it predicts externalizing behaviors in late childhood and early adolescence, when oppositional and conduct problems are becoming a significant concern.

Of note, our measures of approach and EC were entirely behavioral. Across all studies of dual-systems theory to date, to our knowledge, only three behavioral measures have been used (Stoplight task to assess sensation seeking and Tower of London to assess impulse control, Icenogle et al., 2017; Steinberg et al., 2008; and a puzzle box to assess EC, Eisenberg et al., 2009; Lahat et al., 2012, deployed observational measures, but their study was not an explicit test of the dual-systems model). We assessed approach as intensity of positive response (e.g., laughing, squealing, grabbing) in standard temperament episodes (LAB-TAB, Goldsmith & Rothbart, 1993; Kochanska et al., 2007). We assessed EC as the child's ability to delay "consuming" a hedonically positive, desirable stimulus; for example, opening a present or eating

a piece of candy. Those hot EC tasks (a subset from a rich battery) were chosen because of their oft-reported links to externalizing behavior problems. Externalizing and internalizing behaviors were assessed via well-established parent-reported instruments.

Method

Participants

Participants included 102 two-parent families (biological parents and one child, 51 boys), recruited from a college town and surrounding areas in the Midwest. Almost all children were born in 2001. To be included, parents had to be cohabitating (all were married), speak English, and intend to stay in the area for the 5 years following recruitment. Parents ranged in level of academic achievement, from high school (25% of mothers and 30% of fathers) to post-graduate (21% of mothers, 20% of fathers). Family income ranged from less than $40,000 (25%) to over $60,000 (49%). Twenty percent of families included at least one non-White parent. Ninety percent of mothers and 84% of fathers were White, 3% and 8% Hispanic, 2% and 3% African American, 1% and 3% Asian, 1% of mothers Pacific Islanders, and 3% and 2% "other" non-White. Parents provided informed consent to participate in the study, and at age 8, children provided assent. The study was approved by the University of Iowa Institutional Review Board.

Approach and EC were assessed in behavioral paradigms completed during laboratory visits conducted by female experimenters (Es) when children were approximately 25, 38, 52, and 67 months old, videotaped for later coding. There were two laboratory visits at each age, one with each parent (at 38 months, there was a home and a laboratory visit, half of each with each parent). Typically, 15 to 20% of cases were used to establish coding reliability, with subsequent periodic realignments. Child Internalizing and Externalizing behaviors were assessed via parent-reported measures at ages 80, 100, 123, and 147 months (6 ½, 8, 10, and 12 years).

Overview of Measures

Table S1 includes the overview of the design and the ages at which covariates, measures of Approach, EC, Externalizing and Internalizing behaviors were obtained. Details of the measures follow.

Covariates. All models were covaried on child gender and socioeconomic status. Socioeconomic status was defined as the mean of mothers' and fathers' education, coded from 1 to 5 (1 = high school diploma; 5 = Bachelor's degree or more), and income, which ranged from 1 to 8 (1 indicating an income of $10,000 and 8 an income of more than $70,000). Additionally, children's Internalizing problems were included as a covariate. Internalizing was modeled as a latent trait using both mothers' and fathers' ratings of Depression, Generalized Anxiety Disorder, Phobia, Obsessive-Compulsive Disorder, Post-Traumatic Stress Disorder, and Separation Anxiety scales of the Child Symptom Inventory (CSI, Gadow & Sprafkin, 2002) at ages 6 ½, 8, 10, and Adolescent Symptom Inventory (ASI, Gadow & Sprafkin, 1998) at age 12.

Approach. Behavioral measures of Approach were based on LAB-TAB paradigms (Goldsmith & Rothbart, 1993). Details are described in Kochanska et al., (2007). Briefly, the episodes included Puppets (two puppets, operated by E, that engaged the child in a humorous scripted dialog) and Bubbles (child popping bubbles blown by E)[1]. Table S1 describes the specific time points (Puppets, twice at 25 months and once at 38 months; Bubbles, twice at 25 months, and once at 38 and 52 months).

The following coded behaviors, similar across the episodes, were selected to serve as indicators of Approach: discrete positive behaviors (e.g., clapping, banging hands on the table,

[1] We also considered the Snake episode (a pop-up trick can) at 52 and 67 months, but it did not cohere with other paradigms in latent variable models.

waving arms in excitement, Puppets); reversed latency to reach (for Puppets); reversed latency to a high-energy motor act (Bubbles); reversed latency to smiling (all episodes); and intensity of smiling (all episodes). The codes were strongly behaviorally grounded and called for little inference. Reliability across coders for categorical codes (kappas) ranged between .78 and .98, and for continuous codes (alphas) ranged between .85 and .99.

Effortful Control. Details of the behavioral paradigms to assess EC have been described (e.g., Kim et al., 2013). Snack Delay: The child delayed eating a snack until E rang a bell (at 25, 38, and 52 months). Gift Wrap: The child resisted peeking while E wrapped a gift. Gift Bow: The child waited, without touching the wrapped gift, while E left the room to get a bow (both at 25, 38, and 52 months). Gift Bag: The child waited without peeking into a gift bag while E left the room to retrieve a bow (at 25, 52, and 67 months). Dinky Toys: The child chose from among many small toys, while keeping hands on a mat (at 38 and 52 months). Tongue: The child refrained from eating a candy placed on their tongue (at 52 months).

The paradigms were coded as follows. Snack Delay: 0-4, with 4 indicating the child did not eat the snack until E rang the bell. Gift Wrap: 1-5, with 5 indicating the child did not try to peek at the gift. Gift Bow: 1-4 to reflect whether the child touched the gift, and 1-4 to reflect time staying in the seat (the two codes were averaged to create a global score). Gift Bag: Similar to Gift Bow, with scales reflecting looking in the bag and leaving the seat (averaged). Dinky Toys: The length of time that passed before the child chose a toy. Tongue: The length of time that passed before the child ate the candy. As with Approach, all EC codes were strongly behaviorally grounded, and reliability of coding was high. Kappas ranged from .71 to 1.00, and alphas ranged from .81 to 1.00. Codes for repeated tasks were averaged across time points, resulting in six indicators, one for each task reported in Table S1.

Externalizing Behavior. Externalizing behavior included the Overt Aggression scale from the MacArthur Health Behavior Questionnaire (HBQ; Essex et al., 2002), and the sum of the Conduct Disorder and Oppositional Defiant Disorder scales from the CSI at ages 6.5, 8, and 10, and ASI at age 12, which also includes a measure of Antisocial Personality Disorder. Both parents completed all measures at all time points. Scores were averaged across time points, for a total of four indicators (two for each parent).

Missing Data

Nineteen out of 102 cases had some missing data. Missing data analyses were performed using tests developed by Jamshidian and Jalal (2010) and implemented in the 'MissMech' package for R (Jamshidian, Jalal, & Jansen, 2014). Tests identified no significant patterns of missingness, suggesting data were missing completely at random (MCAR).

Latent trait measurement models were developed using maximum-likelihood estimation (FIML). FIML was used to address missing data. FIML is unbiased when data is MCAR (Enders & Bandalos, 2001). Structural equation models were estimated using Bayesian methods, which is also unbiased when data is MCAR (Rubin, 1976).

Latent Trait Models

All latent trait measurement models were developed in R (R Development Core Team, 2010). The process for developing measurement models for each trait was as follows. First, parallel analysis, a method of determining the number of factors in a data set, was performed using the R package 'paran' (Dinno, 2012). Parallel analysis compares the eigenvalues of randomly-generated data sets, comprised of the same number of variables and participants, to the eigenvalues of the observed dataset. Factors should be retained if their observed eigenvalues exceed those of the simulated data sets. Second, an exploratory factor analysis was performed

using the R package 'psych' (Revelle, 2017), with the number of factors determined by the results of the parallel analysis performed in step one. Third, a confirmatory model was estimated using the R package 'lavaan' (Rosseel, 2012). The confirmatory model was defined by loadings greater than 0.3 in the exploratory model. We used the MLR estimator, as it is robust to non-normally distributed indicators. To identify a unidimensional latent trait model for each of the four major constructs, multidimensional CFAs included a general, second-order trait. Fourth, codes that were not statistically significant in the confirmatory model were dropped in an iterative fashion, until all remaining codes were statistically significant. Finally, to reduce the number of parameters in measurement models to an appropriate ratio relative to the sample size (based on simulation studies in Lee and Song, 2004), codes were averaged within first-order traits to create composite indicators. A final CFA was estimated from those composites. The results of this process are summarized for each trait below.

Approach. The variances, covariances, and correlations of the indicators of Approach are reported in Table S2. The final model consisted of three composite indicators (CFI = 1.00, RMSEA = 0.00). The first composite was based on codes from the Puppets paradigm at age 25 months, and the second was made up of codes from the Puppets paradigm at age 38 months. The third composite was measured by codes from the Bubbles paradigm at ages 38 and 52 months. Figure 1A depicts the measurement model for Approach.

Effortful Control. The variances, covariances, and correlations of the indicators of EC are reported in Table S3. In the final model, all six proposed indicators of EC were significant (CFI = 0.90, RMSEA = 0.12). Figure 1B depicts the measurement model for EC.

Externalizing Behavior. The variances, covariances, and correlations of the Externalizing indicators are reported in Table S4. The final model consisted of two composites,

one for mothers' report, and one for fathers' reports (CFI = 0.83, RMSEA = 0.15). Figure 1C depicts the measurement model for Externalizing.

Internalizing Behavior. The variances, covariances, and correlations of the indicators of Internalizing behavior are reported in Table S5. This model, similar to the model of Externalizing, had a factor for each parents' report (CFI = 0.95, RMSEA = 0.09). Figure 1D depicts the measurement model for Internalizing.

[Insert Figure 1 here]

It should be noted that while the values of RMSEA range from 0.00 to 0.15, which is above the generally accepted cutoff of 0.08, the confidence interval of RMSEA for all models included 0.08. Furthermore, RMSEA has been shown to be overly conservative in small samples, and should be interpreted cautiously, if at all (Kenny, Kaniskan, & McCoach, 2015). Variances and covariances of the latent traits and covariates are reported in Table S6.

Structural Analyses

Structural models were estimated using Stan, a C++ based library for Bayesian inference using Markov Chain Monte Carlo sampling (*Stan: A C++ Library for Probability and Sampling, Version 2.8.0*, 2015). Model code is available upon request. Bayesian methods require a prior be specified for each parameter in the model. Priors were chosen based on the guidelines for Bayesian non-linear SEMs presented in Lee (2007), and are reported in Supplement A.

Assessment of model convergence and fit. For each model, three chains were run. Each chain began with 1,000 warm-up iterations that were discarded, followed by 1,000 iterations that were retained for analysis. Model convergence was assessed by Gelman and Rubin's (1992) potential scale reduction factor $\hat{R}$. While there is no strict cutoff for convergence, values less than 1.1 are satisfactory, and values less than 1.05 are preferred. After 2,000 iterations, $\hat{R}$ was

less than 1.03 for all models.

Model fit was assessed using the Widely Applicable Information Criterion (WAIC), a parsimony-adjusted approximation to leave-one-out cross-validation (Gelman, Hwang, & Vehtari, 2013; Vehtari, Gelman, & Gabry, 2015; Watanabe, 2010). Lower values indicate a model predicts new data more accurately and parsimoniously than a model with a higher value of WAIC. WAIC was calculated using the R package 'loo' (Vehtari, Gelman, & Gabry, 2015b).

Results

The results of the structural model predicting Externalizing from Approach and EC are reported below. Given that this model was estimated using Bayesian methods, we report 95% credible intervals (i.e., the range within which the parameter lies with probability = 0.95). If the 95% credible interval does not include zero, the effect is described as significant.

Table 1 reports the model coefficients for the prediction of Externalizing by Approach and EC. The interaction between Approach and EC was significant (*B* = -1.72, *SE* = 0.79, 95% CI [-3.26, -0.17]). In addition, the quadratic effect of EC was significant (*B* = 1.31, *SE* = 0.48, 95% CI [0.48, 2.40]). Internalizing was also a significant predictor of Externalizing (*B* = 1.34, *SE* = 0.49, 95% CI [0.53, 2.45]). In sum, Approach and EC interacted to predict Externalizing. In addition, especially high or low levels of EC relative to Approach also predicted Externalizing. Although Internalizing and Externalizing were comorbid, the effects of Approach and EC on Externalizing remained significant, even when Internalizing problems were covaried.

[Insert Table 1 here]

Figure 2 depicts the regression plane of the full model. The regression plane plots the predicted level of Externalizing as a function of Approach, EC, their quadratic effects and interaction. The axes for Approach and EC span the range of the mean observed latent trait

scores. In general, when children possessed relatively *equal levels of Approach and EC* (i.e., are between the points labeled A and B in the figure), the *risk of Externalizing was lowest*. At *high levels of Approach, low levels of EC predicted greater Externalizing* (i.e., point C). For children who had *very high levels of EC, lower levels of Approach predicted greater Externalizing* (point D). In other words, an imbalance of Approach and EC, in either direction, predicted higher Externalizing scores.

[Insert Figure 2 here]

Figure S1 depicts the simple slope between Approach and Externalizing, conditioned on EC. For those children below the 74th percentile in terms of EC, the slope of Approach is positive, meaning greater Approach predicts more Externalizing. However, for children above the 87th percentile of EC, the simple slope is negative, meaning greater Approach predicts fewer Externalizing problems.

Importantly, to assess the effect of omitting significant quadratic effects (a common practice in the literature), a model with only direct effects and an interaction effect (but no quadratic effects) was fit. The parameter estimates from this model are also reported in Table 1. WAIC for the quadratic model was 5,874.8, and R^2 was 0.64; WAIC for the simple interaction model was 5,933.8, and R^2 was 0.50. In sum, the model with quadratic terms was superior in terms of both WAIC and R^2. Furthermore, omitting quadratic effects resulted in a change in the direction of the interaction between Approach and EC (*B* = 0.25, 95%, *SE* = 0.86, CI [-1.58, 1.65]), and the interaction being no longer significant.

Discussion

The recent proposal of a *dual-system model*, which poses the *imbalance* between approach tendencies and self-regulation as key for an increased risk for externalizing problems

(Nigg, 2006; Steinberg et al., 2008), is important, compelling, and heuristically generative. Empirical cross-sectional evidence, gathered from large samples in multiple cultures, and dovetailing data from neuroscience have produced impressive insights into the causes of commonly occurring risk-taking and other externalizing and disruptive behavior problems in adolescence. Adolescence is depicted as a time when a substantial imbalance occurs: The rapid development of approach tendencies is not matched by the development of self-regulatory mechanisms, which lag behind. That imbalance gives rise to excessive risk-taking and other antisocial behavior problems characteristic for adolescence.

We believe that the imbalance model has potential heuristic value beyond the specific focus on adolescence. In particular, we believe that it can be tested longitudinally, over a large age range, beginning much as early as toddlerhood, given that both approach and self-regulation can be measurable at early age. Toward this end, we have recast the model in an individual differences framework. We assessed both traits four times between ages 2 and 5 ½, using established behavioral laboratory paradigms. Externalizing problems (aggression, opposition, disregard for rules, etc.), assessed from 6 ½ to 12 years by mothers and fathers, served as the outcome measures. Further, we have proposed a robust analytical strategy that may be useful for researchers studying various types of the imbalance or dual-systems models.

Our findings supported an individual-differences framework for the imbalance hypothesis. The young children with a surfeit of approach, relative to EC, developed more externalizing behavior problems in early adolescence. Those children whose approach tendencies were commensurate with their capacity to self-regulate (EC) appeared relatively protected from later externalizing behavior. Thus, a balance of approach and EC promoted adaptive developmental trajectories. Of note, this pattern was specific to “hot” EC, and did not emerge for

"cool" EC tasks (the latter analyses, unreported but available on request, were also conducted).

Rather surprisingly, the opposite imbalance – low approach combined with high EC – also emerged as a liability for externalizing behavior. One possible interpretation might be that this pattern was driven by internalizing problems, comorbid to externalizing problems, as low approach (anhedonia) is a specific liability for depression in both adults and adolescents, and overcontrol is a liability for anxiety (Brown, Chorpita & Barlow, 1998; Clark & Watson, 1991; Forbes & Dahl, 2005; Forbes, Shaw & Dahl, 2007; Nigg, 2000). However, we discounted this possibility, as the effect on externalizing problems remained significant even when comorbid internalizing problems were taken into account. This suggests that an imbalance of approach and EC *in either direction* predicts externalizing behavior problems. Note, however, that Figure 2 reveals that the prototypic imbalance (greater EC than approach) is associated with substantially higher externalizing problems than the inverse (greater approach than EC). Although unanticipated, these findings are consistent with a large body of literature showing that many personality or temperament traits are maladaptive at either extreme (Clark et al., 1994; Frick & Morris, 2004; Widiger & Simonsen, 2005; Wiggins & Pincus, 1994). Coplan, Wilson, Frohlick and Zelenski (2006) examined the four possible configurations of high versus low approach and inhibition, and reported that psychosocial functioning was poorest among children with low approach and high inhibition, a parallel finding. Similarly, low approach as a liability for externalizing is consistent with observed hypo-dopaminergic factors contributing to ADHD (Castallanos & Tannock, 2002). Imaginably, children who are overcontrolled and whose approach tendencies are weak may develop maladaptive emotion regulation strategies that ultimately lead to anger and externalizing problems. This, however, is a question for future research.

Of note, in the current literature, multiple theoretical constructs have been studied as reflecting approach tendencies, self-regulation, and externalizing or disruptive behavior problems. This conceptual heterogeneity makes replication tests of the imbalance hypothesis challenging (Duckworth & Steinberg, 2015). Just as examples, impulsivity, BAS, reward sensitivity, and sensation seeking have all been considered approach tendencies; effortful control, self-regulation, self-control, and executive functioning have been seen as regulatory capacities (see Nigg, 2017, for a review); and risk-taking, substance use, risky sexual activity, and oppositional and defiant behavior have been considered externalizing outcomes (Shulman et al., 2016). In the current work, we focused on young children's traits that can be robustly assessed in the laboratory: Approach, observed in multiple joy-eliciting paradigms, and EC, observed in multiple "hot" delay tasks. Future research that carefully maps the studied relations across a broad range of related constructs would be useful.

This study has several limitations. The sample was small, which is inevitable in a long-term longitudinal study with intensive observational assessments. The accuracy of parameter estimates is a function of the ratio of parameters to the sample size; whereas Lee and Song (2004) show that similar latent variable models have good accuracy and precision in equivalent sample sizes, they do not report statistical power. This is a topic that merits further empirical research. Of course, a much larger sample would allow for the estimation of an autoregressive model with latent trait measurement models at each time point, which would elucidate how developmental trajectories change over time, and how approach and EC interact at each time of assessment. We tested a simpler model because we did not wish to extend the model beyond what the data could support. In doing so, we sacrificed information about change from age 2 to age 5 ½ with regard to approach and EC, and from 6 ½ to 12 years with regard to externalizing

behavior. However, we find prediction over the long developmental span between these two periods to be compelling. Consequently, we hope that the present analyses function as a "proof of concept" for researchers with appropriately structured and powered data sets.

The families came from a low-risk community sample. Ethnic diversity was limited (although note 20% of the families had at least one non-Caucasian parent). Children were generally well functioning and the level of behavior problems was relatively low and generally in the normative range. Nevertheless, variability in externalizing behavior was sufficient to estimate a model with strong loadings (0.56 and 0.78).

Finally, no account of relations between children's temperament traits and their future adjustment is complete without considering the role of the qualities of the parent-child relationship and transactions between the two sets of factors, unfolding over time. Young children with strong approach tendencies and insufficient self-regulation may elicit a distinct, dysfunctional pattern of parental control, characterized by power assertion, frequent prohibitions, and angry discipline tactics, further exacerbating the risks of externalizing problems (Smith et al., 2014). As well, temperament traits and broader ecologies may interact (Ray, Thornton, Frick, Steinberg, & Cauffman, 2016). Those are important avenues for future research inspired by the imbalance hypothesis and dual-system models of antisocial behavior.

Conclusions

An imbalance of approach and self-regulation places children at an increased risk for externalizing behavior. Children with a relative imbalance–whose approach tendencies exceed their self-regulation–were at an elevated risk for externalizing behavior in preadolescence. Demonstrating a broader potential scope for the imbalance hypothesis, children whose self-regulation exceeded their approach were also at elevated risk for later externalizing problems,

although to a much more modest extent. Given the societal and health burdens due to externalizing and risk-taking behavior, and the stability of externalizing behavioral problems over the life span, interventions aimed at modulating both approach and regulation in childhood have the potential effectively to alter, for the better, children's developmental trajectories.

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Table 1

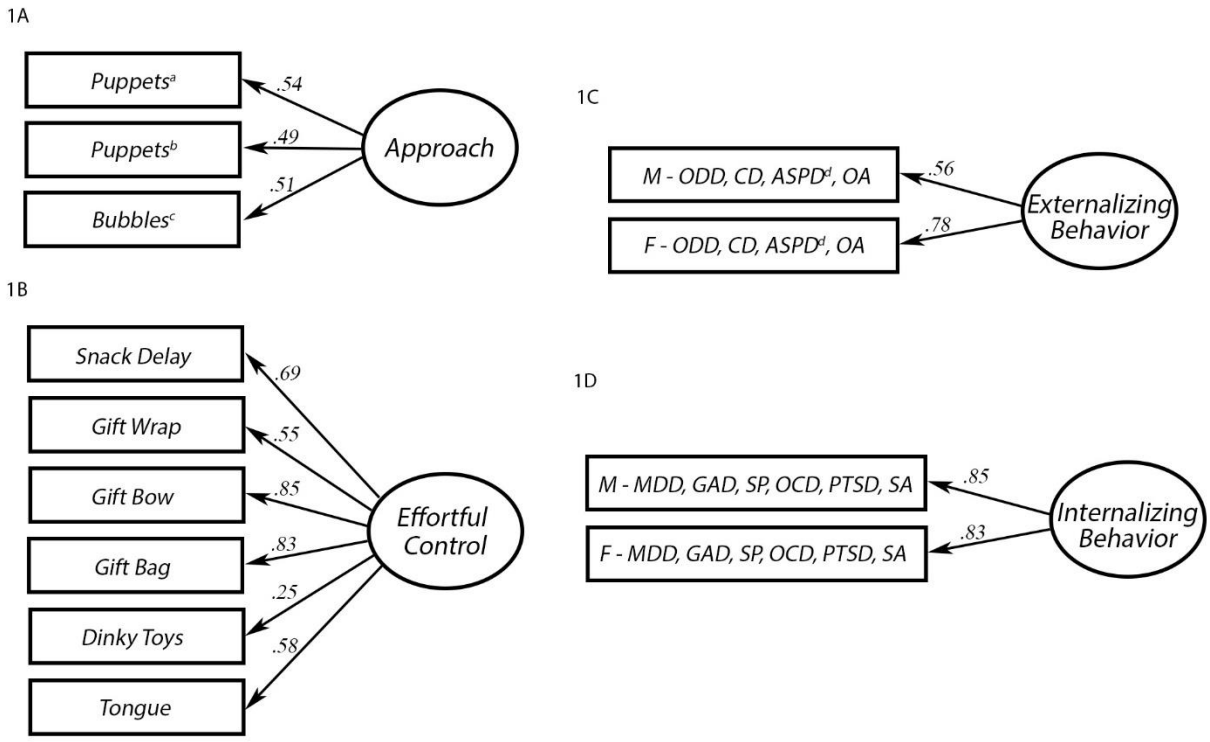
Regression of Externalizing Behavior on Gender, Approach, Effortful Control, and Internalizing

	With quadratic terms			Without quadratic terms		
Predictor	*B*	*SE*	95% CI	*B*	*SE*	95% CI
Gender	1.66	0.56	0.69 to 2.86	1.72	0.56	0.73 to 2.87
SES	0.04	0.23	-0.37 to 0.57	0.04	0.24	-0.41 to 0.55
Internalizing	1.34	0.49	0.53 to 2.45	1.34	0.52	0.50 to 2.51
Approach	1.06	1.01	-1.04 to 2.94	0.28	1.26	-1.99 to 2.64
EC	-0.52	0.86	-2.27 to 1.16	-0.67	0.89	-2.31 to 1.19
Approach × EC	-1.72	0.79	-3.26 to -0.17	0.25	0.86	-1.58 to 1.65
$Approach^2$	0.42	0.58	-0.65 to 1.61			
EC^2	1.31	0.48	0.48 to 2.40			
WAIC	5,874.8			5,933.8		
R^2	0.64			0.50		

Note. Results from models predicting Externalizing (6 ½ to 12y) from Approach and EC (2 to 5½y). The left half of the table reports results from a model with quadratic terms (indicated by the superscript “2”), and the right half a simple interaction model. Omitting quadratic terms prevents detection of the interaction. Since the latent variables are standardized, the standardized and unstandardized parameter estimates are equal. Gender is Males = 2, Females = 1. WAIC = Widely Applicable Information Criterion. EC = Effortful Control. SES = Socioeconomic Status.

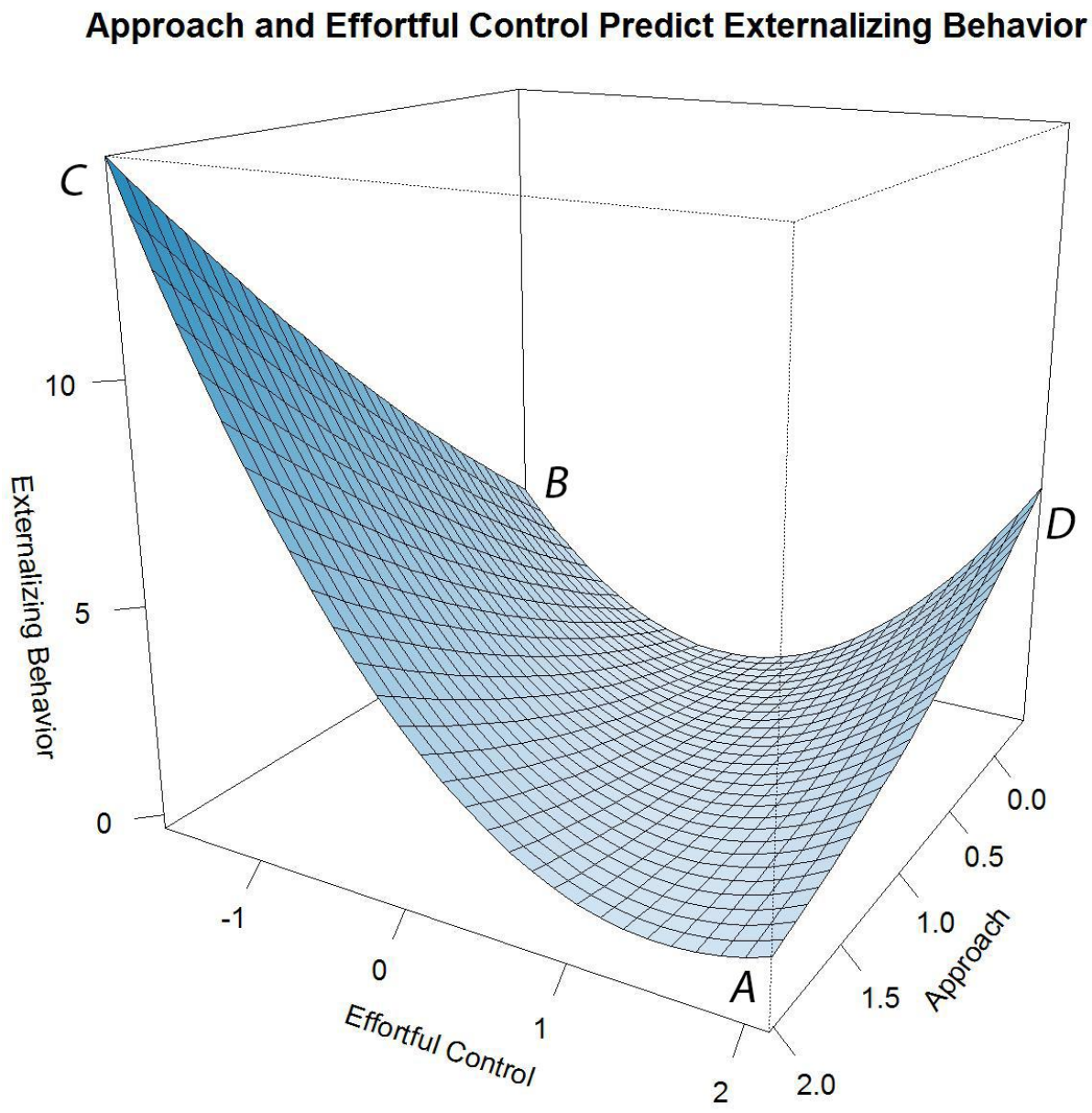
Figure 1

Latent Trait Models of Approach, Effortful Control, Internalizing Behavior and Externalizing Behavior.



Note. All loadings are significant at $p < 0.05$. ODD = Oppositional Defiant Disorder; CD = Conduct Disorder; ASPD = Antisocial Personality Disorder; OA = Overt Aggression; MDD = Major Depressive Disorder; GAD = Generalized Anxiety Disorder; SP = Specific Phobia; OCD = Obsessive Compulsive Disorder; PTSD = Post-Traumatic Stress Disorder; SA = Social Anxiety. [a] Puppets paradigm at 25 months; [b] Puppets paradigm at 38 months; [c] Bubbles at 38 and 52 months. [d] ASPD measured only at 12 years. All other composites are averaged over time points specified in Table S1. M = Mother; F = Father.

Figure 2



Note. The children along the valley from the nearest point of the figure (marked by the letter A) to the farthest (B) have relatively equal degrees of Approach and Effortful Control (EC), and have the lowest rates of Externalizing. The children with an imbalance in either direction, either more Approach then EC (C) or *vice versa* (D), have greater Externalizing behavior.