Received: 30 June 2019 | Revised: 7 May 2020 | Accepted: 8 May 2020

DOI: 10.1111/desc.13040

Developmental Science WILEY

SHORT REPORT

Inhibitory control and set shifting describe different pathways from behavioral inhibition to socially anxious behavior

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Funding information
This research was supported by the National Institute of Mental Health (U01MH093349; U01MH093349-S).

Abstract

Individuals with a behaviorally inhibited (BI) temperament are more likely to develop social anxiety. However, the mechanisms by which socially anxious behavior emerges from BI are unclear. Variation in different forms of top-down control, specifically executive functions (EF), may play distinct roles and characterize differential pathways to social anxiety. Here 291 children were assessed for BI in toddlerhood (ages 2 and 3), parent-reported inhibitory control and set shifting during middle childhood (age 7), and multidimensional assessment of socially anxious behavior completed during late childhood and early adolescence (ages 9 and 12). Structural equation modeling revealed that early variation in BI predicted the development of socially anxious behavior through either higher levels of parent-reported inhibitory control or lower levels of parent-reported set shifting. These data reinforce the notion that top-down control does not uniformly influence relations between temperament and socially anxious behavior. These data suggest novel approaches to thinking about the role of EFs and social anxiety outcomes as children approach adolescence.

KEYWORDS
behavioral inhibition, executive functions, social anxiety, temperament, top-down control

1 | INTRODUCTION

Executive functions (EF) refer to a set of neurocognitive processes that exhibit substantial developmental change throughout childhood and allow for the regulation of thought and behavior (Diamond, 2013; Miyake et al., 2000). EF is typically defined in terms of three moderately correlated, but separable processes, including *inhibitory control*, reflecting the inhibition of prepotent responses; *set shifting*, referring to the ability to shift between tasks or mental sets; and *updating*, referring to the process of updating and monitoring the contents of working memory (Miyake et al., 2000). Better EF skills are generally viewed as adaptive, as they confer positive developmental outcomes, including a reduced incidence of substance use or criminal offences, as well as improved physical health and personal finances (Moffitt et al., 2011). Moreover, higher levels of EF skills are typically associated with reduced anxiety symptoms (Eysenck et al., 2007; Kertz et al., 2016; Lengua, 2003). However, children with a particular temperament, known as "Behavioral Inhibition" (BI), appear to exhibit more complex outcomes based on specific EF abilities (Buzzell et al., 2017; Lahat et al., 2014; McDermott et al., 2009; Thorell et al., 2004; Troller-Renfree et al., 2018; White et al., 2011). Here we focus on two EFs, inhibitory control and set shifting, given prior work linking these processes to anxiety development amongst children with higher levels of BI (Henderson & Wilson, 2017; Henderson et al., 2015).

Behavioral inhibition is characterized by negative reactivity and avoidance of novelty during toddlerhood (Fox et al., 2005; Kagan et al., 1988). By early childhood, children with higher levels of BI,

compared to their peers, are more likely to display social reticence, marked by avoidance of unfamiliar peers during social interactions while maintaining "onlooking behaviors" (Coplan et al., 1994; Degnan et al., 2014). By late childhood and adolescence, children with higher BI, compared to their peers, are also more likely to develop social anxiety (Chronis-Tuscano et al., 2009), with BI associated with a fourfold increase in the odds of developing social anxiety (Clauss & Blackford, 2012). Nevertheless, the exact mechanisms that underlie longitudinal associations between this early temperament and later social anxiety remain unclear. Henderson et al. (2015) and Henderson and Wilson (2017) suggest that the link between BI and later socially anxious behavior is influenced by bottom-up factors, such as novelty detection and attention biases to threat on one hand, as well as top-down factors, such as inhibitory control and set shifting on the other hand. Toward this end, the current paper focuses on how these top-down factors, specifically parental reports of inhibitory control and set shifting, may differentially influence the development of later socially anxious behavior from early BI.

For children with a history of BI, competence in set shifting is protective against the development of anxiety (White et al., 2011). Conversely, inhibitory control actually confers greater risk for anxiety in early childhood (White et al., 2011), and social anxiety in late childhood and early adolescence (Thorell et al., 2004; Troller-Renfree et al., 2018). Initially, it may seem counterintuitive that anxiety would be associated with higher levels of EF ability in inhibitory control, but lower levels in set shifting. However, higher levels of inhibitory control or lower levels of set shifting might both result in a behavioral profile that is characterized by a pattern of inflexible behavior; such inflexible behavior is likely not conducive to social interactions and may therefore increase the likelihood of displaying socially anxious behavior (Henderson & Wilson, 2017; Henderson et al., 2015).

The theoretical framework put forward by Henderson et al. (2015) and Henderson and Wilson (2017) suggests that variation in levels of BI influences the development of EF. Higher BI is thought to be associated with a bottom-up information processing bias, which leads to lower levels of top-down set shifting ability, given that it is more difficult to shift attention when a greater initial bias must first be overcome (Henderson & Wilson, 2017; Henderson et al., 2015). Similarly, this bottom-up information processing bias is thought to drive an over-generalized use of top-down inhibitory control across contexts, which further impairs top-down set shifting (Henderson & Wilson, 2017; Henderson et al., 2015). Ultimately, higher levels of inhibitory control and/or lower levels of set shifting may impair the ability of these children to flexibly interact with peers, particularly within novel social contexts, setting off a cascade of negative social experiences and potentiating risk for socially anxious behavior (Henderson & Wilson, 2017; Henderson et al., 2015). Thus, high levels of inhibitory control or low levels of set shifting ability—both thought to be associated with a rigid, inflexible behavioral profile—could potentially moderate, or mediate, links between early BI and later socially anxious behavior.

Research Highlights

- Behavioral inhibition assessed in toddlerhood longitudinally predicts socially anxious behavior as children approach adolescence.
- Inhibitory control and set shifting mediate this link in opposite directions: greater inhibitory control is associated with increased socially anxious behavior; greater set shifting with less socially anxious behavior.
- These data reinforce the notion that executive functions do not uniformly influence relations between temperament and socially anxious behavior.
- High inhibitory control or low set shifting ability—both thought to be associated with a rigid, inflexible behavioral profile—increase risk for socially anxious behavior.

The theoretical framework put forward by Henderson et al. (2015) and Henderson and Wilson (2017) has not been fully tested and existing support is not without limitations. The study that most closely relates to how different top-down factors might influence the development of socially anxious behavior is described in work by White et al. (2011). This study demonstrated that 2-year-old children with BI are at increased risk for developing anxiety symptoms by age 4 and 5 if they show *either* higher levels of inhibitory control ability *or* lower levels of set shifting ability. However, White et al. (2011) did not specifically test outcomes related to socially anxious behavior, as these do not typically manifests until late childhood or early adolescence (Kessler et al., 2005; Pine et al., 1998). More importantly, the study by White et al. (2011) found that behavioral assessments of EF, specifically inhibitory control and set shifting, differentially *moderated* the link between early BI and later anxiety. In line with the theoretical model of Henderson et al. (2015) and Henderson and Wilson (2017), we suggest that such top-down factors may also *mediate* relations between early BI and later socially anxious behavior. However, it is possible that in order to capture aspects of EF that mediate relations between early BI and later socially anxious behavior requires assessing how EF is applied within social settings. One approach might be to assess EF not using classic laboratory-based behavioral measures, but instead using parental-reports of EF that provide a comprehensive assessment of EF, including how EF is applied within social contexts.

Building on prior work (Henderson et al., 2015; White et al., 2011), the current study employs parental reports of children's EF abilities in order to test whether different top-down factors yield different developmental pathways from early BI to later socially anxious behavior. Towards this end, we leverage the same longitudinal sample originally reported on by White et al. (2011), which assessed BI in toddlerhood (at age 2). In that study, relations between BI, behavioral assessments of EF at age 4, and global levels of anxiety symptoms at age 4 and 5 were analyzed. Given that social anxiety does not typically manifests until late childhood or early adolescence (Kessler

et al., 2005; Pine et al., 1998), the current study analyzes new data collected on this sample up to age 12, to include multidimensional assessment of socially anxious behavior and related social anxiety symptoms in late childhood and early adolescence (at ages 9 and 12) as the outcome of interest. The current study also employs parental reports of inhibitory control and set shifting ability at age 7 as mediators of the link between BI and later socially anxious behavior. For the current study, parental reports of EF were employed for two reasons. First, *both* inhibitory control and set shifting were not assessed using behavioral measures during the midpoint (i.e., approximately age 7) between our predictor (BI at ages 2/3) and our later outcome measure (socially anxious behavior at ages 9/12). Second, parent reports of EF can provide a comprehensive assessment of EF, including how EF is applied within everyday social settings. Organizing these data within a parallel mediation model, we formally tested the nature of risk for socially anxious behavior, hypothesizing that higher levels of BI (ages 2/3) develops into the expression of socially anxious behavior and related social anxiety symptoms (ages 9/12) through the presence of either higher levels of parent-reported inhibitory control or lower levels of parent-reported set shifting during middle childhood (age 7). While our primary hypotheses focus on mediation, we also tested whether parent reports of EF would moderate relations between BI and later socially anxious behavior, based on prior work by White et al. (2011). Additionally, given that prior work showing that levels of social anxiety (Weinstock, 1999) and EF abilities (Else-quest et al., 2006) can differ between males and females, we tested for similar effects in our data and controlled for gender where appropriate.

2 | METHODS

2.1 | Participants

Participants were from a larger longitudinal study (the same used by White et al., 2011), comprised of 291 children (135 male, 156 female) who were originally selected at 4 months of age based on their reactions to novelty in the laboratory (Hane et al., 2008). Based on the initial sample demographics, mothers were 69.4% Caucasian, 16.5% African American, 7.2% Hispanic, 3.1% Asian, 3.4% other, and 0.3% were missing demographic information; 35.7% of mothers reported being graduate school graduates, 41.9% were college graduates, 16.2% were high school graduates, 5.5% reported other forms of education, and 0.7% were missing education information. Between 4 months and 12 years of age, these children and their families were repeatedly assessed using laboratory-based behavioral observations and questionnaire measures. The current study focuses on statistical analyses that include the following data collected from these children: BI assessment at ages 2 and 3 in the laboratory, parent reports of children's EF abilities in middle childhood (age 7), and assessment for *socially anxious behavior* and related social anxiety symptoms via multiple methods/informants at ages 9 and 12. All procedures were approved by the University of Maryland, College Park institutional review board institutional review board; all parents provided written informed consent and children provided assent.

2.2 | Measures

2.2.1 | Behavioral inhibition

Consistent with prior work, children were observed in the laboratory at ages 2 and 3 while they played with novel toys and interacted with unfamiliar adults (Fox et al., 2001; Kagan & Snidman, 1991); BI was coded based on children's proximity to their caregiver and latency to approach or vocalize during these observations. Based on the complete sample of children observed at the 2- and 3-year assessments, average intraclass correlation coefficients were 0.87 and 0.98, respectively. The BI variables approached normality, with skewness and kurtosis both well below 1 at each age (age 2 skewness = −0.514, kurtosis = −0.289; age 3 skewness = 0.522, kurtosis = −0.101); the two BI variables were also correlated (r = 0.328, p < 0.001). Consistent with other work investigating pathways linking BI and later social anxiety symptoms (Buzzell et al., 2017), standardized BI scores were computed for the 2- and 3-year assessments and then combined into a composite BI measure averaging scores across the two assessments (also see Pérez-Edgar et al., 2011). Purely behavioral measures of BI were employed here because this approach eliminates the issue of shared method variance when predicting outcome measures that rely at least partly on parental reports and found to be consistent with related work (e.g., Buzzell et al., 2017).

2.2.2 | Behavior Rating Inventory of Executive Functions

When the children were 7 years of age, their parents completed the Behavior Rating Inventory of Executive Functions (BRIEF), a questionnaire designed to assess real-world expressions of EF in children and adolescents, which includes many items related to EF within social settings (Gioia et al., 2000). The BRIEF contains a total of eight subscales, including an "inhibit" scale and a "shift" scale. The inhibit scale consists of 10 items, with examples being: "Interrupts others," "Has trouble putting the brakes on his/her actions," "Gets out of seat at the wrong times," "Blurts things out." The shift scale consists of eight items, with examples being: "Resists or has trouble accepting a different way to solve a problem with schoolwork, friends, chores, etc.," "Becomes upset with new situations," "Is disturbed by change of teacher or class," "Has trouble getting used to new situations." Thus, parent-reported EF can capture a comprehensive assessment of EF, including how EF is applied within everyday social settings. Reliability estimates identified good internal consistency for each subscale (inhibit, a = 0.9; shift, a = 0.74). To assess levels of inhibitory control ability and set shifting ability, items were summed for the "inhibit" and "shift" scales of the BRIEF, respectively. Because the BRIEF measures

impairments in EF abilities, summed values for the inhibit and shift scales were each multiplied by −1 so that higher values on each of these scales would reflect improved parent-reported inhibitory control or parent-reported set shifting to facilitate interpretation. Note that we use the terms we reserve the terms "inhibitory control" and "set shifting" for the classic behavioral assessments of these EF constructs, and use the terms "parent-reported inhibitory control" and "parent-reported set shifting" when referring to assessment via parent reports.

2.2.3 | Screen for Child Anxiety-Related Disorders

At both the 9- and 12-year visits, parents and children independently completed the Screen for Child Anxiety-Related Disorders (SCARED), a questionnaire assessment of symptoms linked to DSM-IV anxiety disorders (Muris et al., 2004). In order to assess social anxiety symptoms, items for the social phobia subscale of the SCARED were separately summed for parents and children at each age. Reliability estimates identified good internal consistency for the social phobia subscale (9-year parent, a = 0.9; 9-year child, a = 0.78; 12-year parent, a = 0.9; 12-year child, a = 0.87). Parent/child reports of children's social anxiety symptoms at ages 9 and 12 were combined with behavioral assessments of the children's socially anxious behavior, as well as clinical evaluations, to yield a multidimensional/multi-informant assessment of socially anxious behavior and related social anxiety symptoms (described in detail below). However, it is important to note that additional analyses were run that only included parent/child reports on the SCARED and the clinical assessments; such analyses yielded similar results and are reported in Supporting Information.

2.2.4 | Get to know you task

To provide direct observation of socially anxious behavior, participants visited the laboratory at ages 9 and 12 and were seated at a table with unfamiliar peers (one peer at age 9, two peers at age 12). Once seated, the researcher said they needed to go "set a few things up and will be back shortly". The participants were then left alone for 2 min, providing an opportunity to speak with one another. Participants' behaviors were videotaped and coded by trained coders. The *amount of time until participants made their first spontaneous utterance* and the *percentage of time they spoke during the 2-min period* were recorded. The *number of times participants shared information about themselves*, and separately, the *number of times they sought information from others* through questions were also recorded. Furthermore, two behaviors were globally rated (across the 2-min period) on a scale of 1 "completely inappropriate" to 5 "totally appropriate": *appropriateness of conversation* (e.g., flow of conversation, information seeking from peer), and *openness to interaction* (e.g., eye contact in relation to peer, physical orientation in relation to peer). A third behavior, *social ease during interaction*, was also rated globally, but on a scale of 1 "uncomfortable" to 5 "totally comfortable" (e.g., affect and anxious behaviors). All variables were coded independently for each participant; inter-rater reliability for coded behaviors ranged from ICC = 0.78–0.98 at age 9 and ICC = 0.89–0.98 at age 12. Where appropriate, coded variables were reverse-scored so that higher values would relate to greater socially anxious behavior. Separate exploratory factor analyses for the variables coded at age 9 and 12 suggested that single factors best explained all variables at each time point. Therefore, all variables at each time point were *Z*-scored and then averaged to create composites capturing socially anxious behavior during the social interaction task at each age. See Supporting Information for analyses that do not involve the get to know you (GTKY) data.

2.2.5 | Clinical interviews

Semi-structured diagnostic interviews (Kiddie Schedule for Affective Disorders and Schizophrenia) were completed for children and parents at the 9- and 12-year time points. All interviews were conducted under the supervision of diagnostic experts. Final diagnoses were made by expert consensus; audiotapes for 26.6% of interviews were reviewed for reliability, yielding exceptionally high reliability for anxiety diagnoses (k = 0.911). The present study focused on clinically significant social anxiety, defined by clinical diagnosis.

2.3 | Analytic plan

2.3.1 | Preliminary analyses

Prior work has demonstrated that levels of social anxiety (Weinstock, 1999), as well as EF abilities (Else-quest et al., 2006) can differ between males and females. Therefore, we first performed a series of preliminary *t*-tests to determine whether parent-reported inhibitory control, parent-reported set shifting, or a composite created from the continuous measures of socially anxious behavior and related social anxiety symptoms differed as a function of gender. For completeness, we also tested whether BI differed as a function of gender. Significant gender differences in overall levels of parent-reported inhibitory control (t = 2.86, p = 0.005) and the socially anxious behavior composite (t = 2.18, p = 0.03) were present, such that boys exhibited lower mean levels of parent-reported inhibitory control and girls displayed higher mean levels for the socially anxious behavior composite; for this reason, subsequent structural equation modeling (SEM) controlled for the effect of gender on both of these constructs (see Supporting Information for multigroup SEM analyses that yield similar results). Levels of parent-reported set shifting (t = 1.87, p = 0.063) and BI (t = 0.37, p = 0.713) did not differ based on gender. A full correlation matrix for all variables can be found in Table 1. In the Supporting Information, we report that study variables were unrelated to IQ.

TABLE 1 Descriptive statistics and correlations for all study variables

	M	*SD*	2	3	4	5	6	7	8	9	10	11
1. 2/3-year BI temperament	−0.005	0.466	0.137	−0.163*	0.180*	0.204**	0.126	0.055	0.072	0.166*	0.029	0.242**
2. 7-year parent-reported IC	−16.140	4.256		0.312**	0.090	0.065	0.043	0.204*	0.200*	0.103	0.100	0.071
3. 7-year parent-reported SS	−12.286	2.776			−0.204*	−0.290**	−0.201*	−0.163	−0.010	−0.040	−0.072	−0.245*
4. 9-year parent-reported	4.003	3.577				0.620**	0.272**	0.429**	0.178*	0.269**	0.272**	0.270**
5. 12-year parent-reported	3.818	3.449					0.332**	0.444**	0.140	0.190*	0.302**	0.318**
6. 9-year child report	5.436	3.131						0.358**	0.188*	0.088	0.335**	0.240*
7. 12-year child report	4.938	3.576							0.186*	0.214**	0.287**	0.343**
8. 9-year GTKY task	−0.030	0.848								0.027**	0.197*	0.091
9. 12-year GTKY task	0.047	0.780									0.185	0.173
10. 9-year clinical diagnoses	—	—										0.166
11. 12-year clinical diagnoses	—	—										

Abbreviations: BI, behavioral inhibition; GTKY, get to know you; IC, inhibitory control; SS, set shifting.

*$p < 0.05$.

**$p < 0.01$.

2.3.2 | Socially anxious behavior latent factor

In order to create a multidimensional/multi-informant assessment of socially anxious behavior and related social anxiety symptoms during late childhood and early adolescence, the observed socially anxious behavior composite associated with the GTKY task, child, and parent reports on the social phobia scale of the SCARED, and clinical diagnoses of social anxiety, each from the 9- and 12-year time points, were employed as indicators. Within a SEM framework, these eight indicators were used to estimate a latent factor capturing socially anxious behavior and related social anxiety symptoms. Given repeated assessment of each indicator at ages 9 and 12, error terms for the individual indicators were allowed to co-vary across time points. The variance of the socially anxious behavior latent factor was set to 1 to scale the indicator variables. Model fit was assessed using a combination of three metrics, including: root mean square error of approximation (RMSEA), comparative fit index (CFI) and Standardized root mean square residual (SRMR). Crucially, the single-factor model of socially anxious behavior and related social anxiety symptoms yielded excellent model fit (RMSEA < 0.001, CFI = 1.0, SRMR = 0.032) and was therefore employed in subsequent path models testing for mediation (described below). In the Supporting Information, we provide further details on model fit for the single-factor model of socially anxious behavior; we also demonstrate that all mediation results remained significant regardless of whether parent reports on the SCARED were included, whether only 12-year data were included, or whether the GTKY behavioral task data were included in the latent factor.

2.3.3 | Model of BI risk for socially anxious behavior

The BI composite (assessed at 2/3 years) was modeled as a predictor of the socially anxious behavior latent factor. The effect of variation in levels of BI on the socially anxious behavior factor was further expanded to include two parallel mediation pathways through either levels of parent-reported inhibitory control or levels of parent-reported set shifting (each assessed at age 7). As mentioned above, summed values for the inhibit and shift scales were each multiplied by −1 so that higher values on each of these scales would reflect improved parent-reported inhibitory control or parent-reported set shifting, which facilitates interpretation of the model. Significance of the direct, indirect, and total effects of BI levels on the socially anxious behavior latent factor was tested using a maximum likelihood estimator and evaluated across 10,000 bias-corrected bootstrap samples. Given the use of bootstrapping, unstandardized parameter estimates and bias-corrected 95% confidence intervals are reported for all inferential statistics; standardized estimates (β) are additionally reported as measures of effect size. Note that the total effect of BI levels on the socially anxious behavior factor tests the hypothesis that BI variation predicts later socially anxious behavior, whereas the two indirect effects evaluate the critical tests of *how* BI increases risk for socially anxious behavior. The Supporting Information reports on additional models that test the robustness of the mediation results after removing various indicators for the socially anxious behavior latent factor. The Supporting Information also reports on an expanded model to test for moderation, and moderated-mediation based on parent-reported EF and BI, respectively. That is, while our primary hypotheses focus on mediation, the expanded model tests whether parent reports of EF moderate relations between BI and later socially anxious behavior, or alternatively, whether any identified mediation results are moderated by initial levels of BI.

Based on prior work (Else-quest et al., 2006; Weinstock, 1999) and our preliminary analyses demonstrating that levels of parent-reported inhibitory control and socially anxious behavior differ across males and females, gender was included as a covariate predicting levels of parent-reported inhibitory control and the latent factor of socially anxious behavior (see Supporting Information for multigroup SEM analyses that yield similar results). All 291 participants were included in the statistical analyses, with missing data accounted for by using full information maximum likelihood estimation (see Supporting Information for details on missing data for each variable). Little's MCAR test, which is the most common method of testing whether data are missing completely at random, was computed (Little, 1988). Little's MCAR test was not significant (χ^2 = 238.73, *df* = 259, *p* = 0.812), supporting the notion that the data were missing completely at random and unlikely to yield biased results. Overall model fit was evaluated using a combination of: RMSEA, CFI, and SRMR. Structural equation modeling was implemented in Mplus version 7.3 (Muthén & Muthén, 2012), whereas preliminary analyses were performed using SPSS version 25.0 (IBM Corp.).

3 | RESULTS

3.1 | Model of BI risk for socially anxious behavior

The model fit the data well (RMSEA = 0.032, CFI = 0.950, SRMR = 0.059; see Figure 1 and Table 2). Consistent with prior work, the total effect of BI variation on the latent factor of socially anxious behavior and related social anxiety symptoms was significant (*B* = 0.564, 95% CI = 0.017–1.155; β = 0.221), confirming that higher levels of toddlerhood BI longitudinally predicts increased socially anxious behavior in late childhood and early adolescence. Higher levels of BI were also found to significantly predict increased levels of parent-reported inhibitory control (*B* = 1.208, 95% CI = 0.022–2.365; β = 0.133) and lower levels of parent-reported set shifting (*B* = −0.975, 95% CI = −1.958 to −0.023; β = −0.164) in middle childhood. Critically, both indirect effects of BI on later socially anxious behavior, through either higher levels of parent-reported inhibitory control (*B* = 0.092, 95% CI = 0.006–0.255; β = 0.036) or lower levels of parent-reported set shifting (*B* = 0.174, 95% CI = 0.006–0.479; β = 0.068), were significant. Collectively, this pattern of results suggests two possible pathways through which early BI leads to socially anxious behavior include: higher levels of parent-reported inhibitory control or lower levels of parent-reported set shifting. Moreover, an

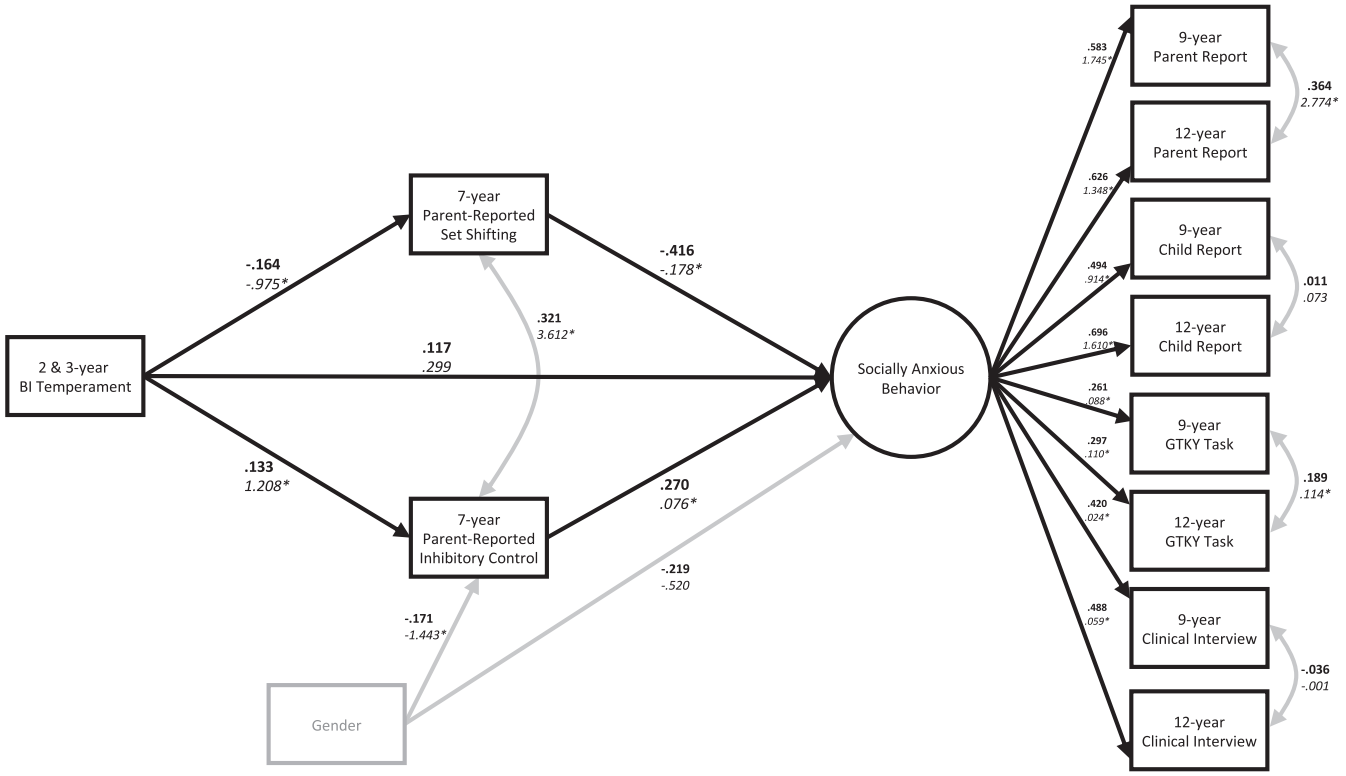

FIGURE 1 Structural equation model of the two-pathway model of behaviorally inhibited (BI) risk for socially anxious behavior. Standardized parameter estimates (β) are presented, in bold font, as measures of effect size only. Unstandardized parameter estimates, reported in italics, were used for all inferential statistics (* denotes significance using a 95% bias-corrected bootstrapped confidence interval). Both indirect effects of BI on later socially anxious behavior, through either higher levels of parent-reported inhibitory control (B = 0.092, 95% CI [0.006–0.255]; β = 0.036) or lower levels of parent-reported set shifting (B = 0.174, 95% CI [0.006–0.479]; β = 0.068), were significant. Note that for ease of interpretation, summed values for the inhibit and shift scales were each multiplied by −1 so that higher values on each of these scales would reflect improved inhibitory control or shifting ability

TABLE 2 Indirect, direct and total effects for mediation model

Effects from BI to SA	LL 2.5%	LL 5%	*B*	UL 5%	UL 2.5%	*β*
Total[a]	0.017	0.100	0.564	1.032	1.155	0.055
Total indirect[a]	0.069	0.093	0.265	0.547	0.612	0.060
BI → IC → SA[a]	0.006	0.017	0.092	0.224	0.255	0.148
BI → SS → SA[a]	0.006	0.029	0.174	0.416	0.479	0.155
Direct	−0.188	−0.111	0.299	0.689	0.785	0.229

Standardized estimates (β) presented as measures of effect size only.

Abbreviations: BI, behavioral inhibition; IC, parent-reported inhibitory control; LL, lower level; SA, socially anxious behavior; SS, parent-reported set shifting; UL, upper level.

[a]Indicates significance using a 95% confidence interval around unstandardized estimate (*B*).

expanded model (described in Supporting Information) revealed no evidence for the presence of moderation (or moderated mediation) via parent-reported EF or BI, respectively.

4 | DISCUSSION

The current study investigated the role of EF, specifically parent-reported inhibitory control and parent-reported set shifting, in longitudinal associations between early BI temperament and later socially anxious behavior. While higher levels of EF abilities are generally viewed as adaptive and conferring positive developmental outcomes (Eysenck et al., 2007; Moffitt et al., 2011), we find that these abilities mediate links between temperament and socially anxious behavior in opposing directions—greater parent-reported inhibitory control was associated with *more* socially anxious behavior; greater parent-reported set shifting with *less* socially anxious behavior. This model reinforces the notion that EFs do not uniformly influence

relations between early temperament and later socially anxious behavior, suggesting novel approaches to thinking about the role of EF skills and social outcomes in childhood.

The statistical model of BI risk for socially anxious behavior tested here is in line with a larger theoretical framework put forward by Henderson et al. (2015) and Henderson and Wilson (2017), which suggests that BI influences the development of EF, which in turn confers risk for socially anxious behavior. In particular, Henderson et al. (2015) and Henderson and Wilson (2017) suggest that BI drives an overgeneralized use of inhibitory control and impairments in set shifting, yielding an inflexible behavioral profile that is not conducive to engaging in social interactions with peers. In line with this theoretical framework, the current study provides evidence that BI leads to later socially anxious behavior through higher levels of parent-reported inhibitory control or lower levels of parent-reported set shifting, which are both thought to be associated with a rigid, inflexible behavioral profile. Nonetheless, it is important to note that the although each variable in the model was time-lagged, the directionality of all effects should be interpreted with caution, as it is not possible to test the opposite directionality of each effect with the data available at each time point.

The current study builds directly on prior findings reported by White et al. (2011), where 2-year-old children with BI were found to be at increased risk for developing global anxiety symptoms (at ages 4 and 5) if they exhibited either higher levels of inhibitory control ability or lower levels of set shifting, which were assessed via classic, behavioral indices of EF at age 4. However, it is important to note critical differences between previous work by White et al. (2011) and the current study. First, the current study focuses on socially anxious behavior and related social anxiety symptoms that were assessed during late childhood and early adolescence—a critical window for the emergence of *social* anxiety—in contrast to the assessment of early childhood anxiety symptoms in the study by White et al. (2011). Second, the study of White et al. (2011) demonstrated that either higher levels of inhibitory control or lower levels of set shifting serve as *moderate* risk for later anxiety. In contrast, the current study identifies novel pathways linking early BI and later socially anxious behavior through *mediation* analyses that focus on *parent reports* of EF (via the BRIEF).

The current study assessed socially anxious behavior as children approach adolescence (ages 9–12), a time when there is a steep rise in social anxiety symptoms (Kessler et al., 2005; Pine et al., 1998); this may allow more time for the unfolding of the mediator and socially anxious behavior. However, there are two more possible explanations for why the current study identified mediation, whereas prior work identified moderation effects. The first possibility is that, because the current study assessed parent reports of EF several years later than the prior study of White et al. (2011), this may have allowed more time for BI to influence development of EF (or at least parent-reports of EF). This notion is in line with the theoretical framework put forward by Henderson et al. (2015) and Henderson and Wilson (2017), which hypothesizes that variation in BI influences the development of EF abilities. However, the second possibility is that parent reports of EF more closely relate to how children apply EF abilities within everyday social settings. These two possibilities are not mutually exclusive. Given widespread interest in the development of EF, future work should seek to more fundamentally understand how age and method of assessment influence various associations with EF abilities.

Children's EF abilities are commonly assessed through either parental reports or laboratory-based assessments, with costs and benefits to each approach (Aron, 2011; Toplak et al., 2009). In general, laboratory-based assessments of EFs have the benefit of allowing for stricter experimental control, but may be limited in their ecological validity (Aron, 2011), which may explain modest correlations between laboratory-based assessments and reports of EF behaviors outside the laboratory setting (Mcauley et al., 2010; Toplak et al., 2009). One reason for employing parental reports of EF in the current study was because behavioral assessments of *both* of these EF constructs were not available for the sample during the midpoint (approximately age 7) between our predictor (BI at ages 2/3) and outcome (socially anxious behavior at ages 9/12) of interest. However, parent reports of EF may also offer a complimentary benefit to traditional, laboratory-based assessment of EF: they may provide a comprehensive assessment of EF that includes how children apply EF within everyday social settings. In particular, the BRIEF questionnaire requires parents to report on their children's EF abilities via a number of items that refers to social settings.

It is also worth noting that a benefit of parental reports is that they can be assessed quickly and at minimal cost, providing a more practical and clinically viable assessment approach. When considering potential applications of the two-pathway model of BI risk for social anxiety, the practical aspects of parental assessments of EF abilities become increasingly prominent. For example, rapid assessments of EF abilities via parental reports might inform whether to provide an intervention that targets either inhibitory control or set shifting, specifically. Ultimately, there remain costs and benefits to either laboratory-based assessments or parental reports of EF abilities and future studies leveraging *both* approaches during middle childhood are needed to fully comprehend the role of EF in developmental relations between early BI and later social anxiety. Additionally, laboratory-based behavioral measures of EF that manipulate the social context could prove particularly informative.

In conclusion, the current study demonstrates that higher levels of BI in toddlerhood confer later risk for socially anxious behavior through the development of either higher parent-reported inhibitory control or lower levels of parent-reported set shifting. Higher inhibitory control and lower set shifting ability are both thought to impair the capacity for children to engage in flexible social interactions with their peers, conferring increased risk for socially anxious behavior. This model of BI risk for socially anxious behavior is consistent with existing theoretical work (Henderson & Wilson, 2017; Henderson et al., 2015), and extends previous empirical findings that identified how behavioral, as opposed parent reports of EF, moderate relations between early BI and later anxiety. At a broad level, these data

suggest novel approaches to thinking about the role of EF skills and social outcomes in childhood and have implications for intervention work as well.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS

N. A. Fox and H. A. Henderson developed the study concept and design. M. E. Bowers and S. V. Troller-Renfree assisted in data collection, with all data collection efforts overseen by N. A. Fox, H. A. Henderson, and C. Chronis-Tuscano. Coding of behavioral data was overseen by H. A. Henderson. G. A. Buzzell performed the primary data analysis and interpretation, with additional assistance from M. E. Bowers and S. Morales, all under the supervision of N. A. Fox, H. A. Henderson, and D. S. Pine. G. A. Buzzell drafted the manuscript, with critical revisions by all other authors. All authors approved the final version of the manuscript for submission.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the authors upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

How to cite this article: Buzzell GA, Morales S, Bowers ME, et al. Inhibitory control and set shifting describe different pathways from behavioral inhibition to socially anxious behavior. *Dev Sci*. 2020;00:e13040. https://doi.org/10.1111/desc.13040