Infant behavioral inhibition predicts personality and social outcomes three decades later

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Does infant temperament predict adult personality and life-course patterns? To date, there is scant evidence examining relations between child temperament and adult outcomes, and extant research has relied on limited methods for measuring temperament such as maternal report. This prospective longitudinal study followed a cohort of infants (n = 165) for three decades to examine whether infant behavioral inhibition, a temperament characterized by cautious and fearful behaviors to unfamiliar situations, shapes long-term personality, social relationships, vocational/education, and mental health outcomes in adulthood. At age 14 mo, behavioral inhibition was assessed using an observation paradigm. In adolescence (15 y; n = 115), error monitoring event-related potentials were measured in a flanker task. In adulthood (26 y; n = 109), personality, psychopathology, and sociodemographics were self-reported using questionnaires. We found that infants with higher levels of behavioral inhibition at 14 mo grew up to become more reserved and introverted adults (β = 0.34) with lower social functioning with friends and family (β = −0.23) at age 26. Infant behavioral inhibition was also a specific risk factor for adult internalizing (i.e., anxiety and depression, β = 0.20) psychopathology, rather than a transdiagnostic risk for general and externalizing psychopathology. We identified a neurophysiologic mechanism underlying risk and resilience for later psychopathology. Heightened error monitoring in adolescence moderated higher levels of adult internalizing psychopathology among behaviorally inhibited individuals. These findings suggest meaningful continuity between infant temperament and the development of adult personality. They provide the earliest evidence suggesting that the foundation of long-term well-being is rooted in individual differences in temperament observed in infancy.

temperament | behavioral inhibition | personality | lifespan

Temperament refers to stable individual differences in behavioral and emotional reactivity observed in infancy that serve as foundations for later personality. One ubiquitous temperamental trait that is heritable and conserved in our evolutionary history is behavioral inhibition (BI) (1–3). In humans, infants identified with BI are characterized by their overly cautious, fearful, and avoidant responses to unfamiliar people, objects, and situations compared to noninhibited infants (1). Similarly, across species of nonhuman animals, BI is captured by neophobic and timid behaviors. The enduring nature of this trait is evidenced in its moderate stability across toddlerhood to middle childhood (4). BI is known to influence childhood social and emotional functioning (5–8), as inhibited children show difficulties in peer interactions, express social withdrawal (5–7), and are at a 4- to 6-fold increased risk for developing anxiety disorders, particularly social anxiety (9, 10) although only an estimated 40% will develop these disorders (10). These findings foreshadow difficulties related to psychosocial outcomes in adulthood, a period with new challenges in achieving financial independence, vocational goals, and maintaining multiple social relationships. Yet, little is known about the life-course sequalae of children who began life with an inhibited temperament because longer-term longitudinal studies are rare and costly.

Over the last three decades, only two prospective longitudinal studies spanning early childhood to adulthood have examined the long-term outcomes of human child temperament. The Dunedin cohort reported that inhibited children at age 3 were at greater risk for depression at age 21 (11) and continued to be introverted and submissive adults with less positive emotion at age 26 (12). The Munich Longitudinal Study on the Genesis of Individual Competencies reported that inhibited children at ages 4–6 delayed transitions to social roles at age 23, as they took longer to get a full-time job, a stable romantic partner, and leave their parents' home (13). Additionally, internalizing problems (e.g., anxiety and depression) were evidenced in a subgroup who as children scored on the upper percentiles of inhibition (13). In a third cohort, inhibited children at ages 8–12 reported less positive and less active social involvement at ages 17–24 (14). These findings converge with longitudinal studies reporting associations between shyness in middle childhood (age 8) and delays in marriage, parenthood, career establishment (15, 16), greater risk for depression, social anxiety, substance-use disorders (17), and lower social functioning (18) if shyness persisted until age 30. Despite the valuable information generated from these studies, the existing work contains methodological weaknesses in the assessment of BI and several gaps of

Significance

Children show different temperamental styles early in development. Whether temperament predicts who children become as adults and how early we can predict these outcomes have been long-standing questions of interest to the scientific and public community. The current study used rigorous methods to characterize an inhibited temperament by 14 mo of age in a cohort of infants and followed them for three decades. We provide the strongest and earliest evidence showing that infants with an inhibited temperament at 14 mo became introverted adults, with poorer functioning in some social and mental health domains. Also, brain activity underlying cognitive control in adolescence was associated with adult mental health. These findings highlight the lasting influence of early temperament on social-emotional development.

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knowledge remain of interest to research on the development of temperament.

First, all of the aforementioned studies spanning childhood to adulthood relied on limited methods to characterize BI, including parent- or teacher-report questionnaires or ratings by an examiner while children completed cognitive tests, rather than standardized exposures to unfamiliar situations (11–13). Questionnaires are subjective ratings reflecting the parents' conception of the child's behavior, as such, these ratings are subject to biases based on the parents' characteristics. Similarly, assessment of BI during cognitive tests may generate limited variability in socially inhibited behaviors, because children's behaviors during cognitive tests may reflect specific features of these tests (e.g., performance anxiety) as opposed to broader aspects of temperament (12, 13). The present study uses a more rigorous methodology by examining blinded-observer ratings of BI when infants confronted various standardized unfamiliar situations in the laboratory and their associations with adult outcomes (Fig. 1, path A). Second, it is unknown how early one can foretell adult life-course outcomes based on temperamental characteristics. The earliest temperament data collected by prior longitudinal studies into adulthood were at age 3 (11, 12), although BI can be reliably observed by the first year of life (7). To provide the earliest evidence, the present study assessed BI at 14 mo of age.

Third, most psychiatric disorders do not suddenly appear in adulthood; they have onsets in childhood and adolescence, are persistent, and are highly comorbid (~60%) over time (19). Aligning with these facts, current models assert the latent structure of psychopathology is best represented by a general psychopathology ("P") factor capturing common features across various disorder spectra, and specific internalizing and externalizing factors capturing unique features (20–22). Given that one psychiatric condition often evolves over time to manifest as multiple cooccurring psychiatric conditions, we expect worse mental health progression of BI children because they already showed a higher prevalence of anxiety disorders in childhood compared to noninhibited children (9, 10). To identify whether BI might serve as an early transdiagnostic risk for a liability to general psychopathology linked to several conditions or a specific risk for internalizing conditions, we adopted the general psychopathology model.

Finally, limited research on temperament has identified neurophysiological processes that underlie individual differences in risk and resilience for later psychopathology. This area of research is important, because many BI children do not go on to have internalizing problems in adolescence and adulthood, although BI significantly increases this risk (10). Overrecruitment and underrecruitment of the brain's error monitoring system has been thought to underlie maladaptive cognitive processes that modulate different facets of psychopathology (23). The error-related negativity (ERN), a mediofrontal negative deflection following an erroneous response (24), is a well-validated neurophysiological measure with a functional role in detecting errors. The magnitude of the ERN reflects the degree to which an individual is monitoring their behavior and is sensitive to errors. A reduced ERN, indicative of less error monitoring, is associated with externalizing conditions and traits linked to disinhibition (e.g., substance use and impulsivity) (25). In contrast, an increased ERN, indicative of heightened error monitoring, is associated with internalizing conditions, predominantly anxiety and less consistently with depression in children, adolescents (26–28), and adults (23, 26, 29, 30), as well as with high and stable levels of BI across childhood (31, 32). This overrecruitment of the error monitoring system increases risk for psychopathology among BI children as it distinguishes between BI children who face relatively high versus low risk for anxiety disorders in adolescence (31, 32). However, prospective studies examining how BI and neurophysiological mechanisms modify outcomes beyond adolescence are lacking (Fig. 1, path B). Based on prior work, which suggests that not all BI children develop anxiety disorders (9, 10) and the ERN amplitude moderates risk for adolescent anxiety (31, 32), we examined whether the ERN moderates the association between infant BI and adult psychopathology.

In this prospective longitudinal study, we followed a cohort of infants for three decades to examine whether infant BI predicts long-term personality, social relationships, vocational/education, and mental health outcomes in adulthood. We had two goals: 1) to determine the association between infant BI and reserved adult personality, levels of functioning, and psychopathology factors in adulthood; and 2) to examine whether the ERN moderates the association between infant BI and psychopathology factors in adulthood. To address limitations of prior studies, BI was assessed using behavioral observations when participants were 14 mo of age. Participants were exposed to various novel situations in the laboratory and inhibited behavioral responses were objectively coded by blinded observers (7). In adolescence, age 15, participants completed a flanker task, during which electroencephalogram was acquired to measure the ERN (31).

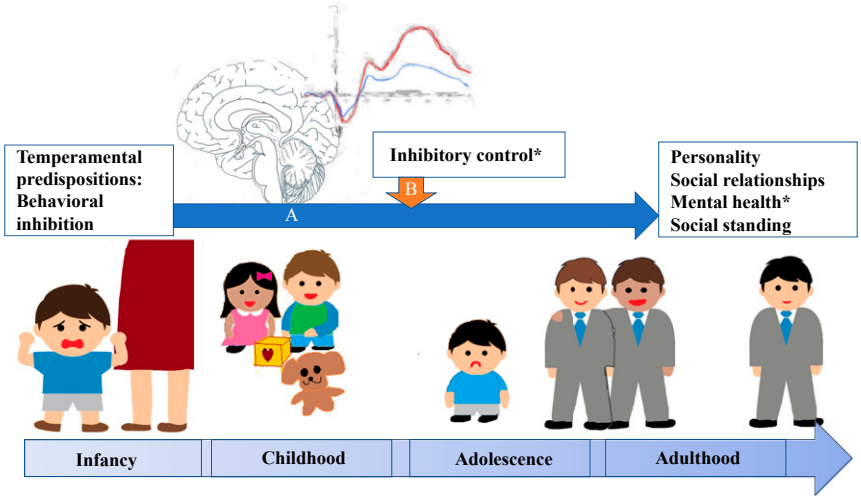

Fig. 1. A lifespan model of temperamental influences on personality and social-emotional development, as well as processes. *Empirical tests of path B were hypothesized for mental health outcomes only.

In adulthood, at age 26, participants completed self-report questionnaires on personality, psychopathology, and sociodemographics.

Results

Descriptive Statistics. Sample characteristics in adulthood are displayed in Table 1. The majority (68.6%) of this sample was in a romantic relationship, only 23.9% were married or engaged and 9.6% had children. These low rates of marriage and parenthood converge with national statistics in 2018 (US Census Bureau) showing the age of first marriage averages at 28.8 y and 29% of people ages 18–34 are married. The proportion of this sample with bachelor's degrees (86.2%) is higher than the national average (35%) for people ages 25 y and above in the year 2018 (US Census Bureau). Additionally, 32.1% of this sample completed an advanced degree. In terms of social standing, 26.6% have higher professional, managerial, and administrative occupations; 32.1% have lower professional, managerial, and administrative occupations; 20.1% have intermediate occupations, worked for small employers, or were self-employed; 16.5% have lower supervisory and routine occupations; and 4.6% were unemployed students. Bivariate correlations and descriptive statistics of variables are displayed in *SI Appendix*, Tables S2 and S3.

Effect of 14-mo BI on Life-Course Outcomes at Age 26. The first question addressed whether 14-mo BI predicted life course outcomes at age 26. These associations are shown in Fig. 2. For latent factors of personality and social functioning, we found that higher levels of infant BI predicted a more reserved personality, $\beta = 0.34$, $P < 0.001$ (*SI Appendix*, Table S7), and lower social functioning with friends and family, $\beta = -0.23$, $P = 0.021$ (*SI Appendix*, Table S8*A*). For romantic relationship outcomes, higher levels of infant BI were related to fewer romantic relationships in the past 10 y, $\beta = -0.27$, $P = 0.012$, but not related to whether participants were married/engaged, $\beta = 0.13$, $P = 0.220$; in a current relationship, $\beta = 0.17$, $P = 0.269$; or parents, $\beta = -0.23$, $P = 0.386$ (*SI Appendix*, Table S8*B*). For education/career outcomes, infant BI did not predict education or career attainment, $\beta = -0.06$, $P = 0.553$ (*SI Appendix*, Table S9). For latent psychopathology factors, infant BI predicted higher levels of the internalizing factor, $\beta = 0.20$, $P = 0.037$, but not the externalizing, $\beta = -0.11$, $P = 0.315$, or general psychopathology, $\beta = 0.14$, $P = 0.112$, factors (*SI Appendix*, Table S10).

The Role of 15-y ERN on 14-mo BI and Psychopathology Factors at Age 26. The second question addressed whether neurophysiologic indices of error monitoring moderated the effect of 14-mo BI on psychopathology factors at age 26. We found interactive effects between infant BI and the peak ERN amplitude in predicting the internalizing psychopathology factor, $\beta = -0.32$, $P = 0.007$ (*SI Appendix*, Table S11*A*). This interaction is plotted in Fig. 3 with 95% CIs indicating the region of significance: A significant and positive association between BI and internalizing psychopathology in adulthood was evidenced only among individuals who showed more negative (larger) amplitudes of the ERN (i.e., < 0.75 SD), but not among those with more positive (smaller) amplitudes. There were no significant interactive effects in predicting externalizing, $\beta = -0.03$, $P = 0.717$, or general psychopathology, $\beta = 0.03$, $P = 0.810$, factors. This interactive effect held in sensitivity analyses testing ERN mean amplitude and difference scores (i.e., ERN minus correct-related negativity) and in incongruent trials only (*SI Appendix*, Tables S11 *B–D* and S12).

Discussion

Researchers have long viewed temperamental qualities as biological predispositions; they are enduring traits that do not simply go away; and they set the foundation for the development of a richer personality. However, few studies have been in the position to show these empirical relations, and no study has examined these relations using temperament in the first year of life. This prospective longitudinal study uses behavioral observations of infant BI at 14 mo of age and data spanning 26 y to examine how temperament shapes adult life-course outcomes. Our results revealed three notable findings.

First, we report continuity between infant temperament and adult personality based on interindividual differences (i.e., relative

Table 1. Sample characteristics in adulthood at age 26

	M or *n*	SD or %
Age (range = 24–28)	26.56	1.44
Sex (female)	62	56.9%
Married or engaged	26	23.9%
In a relationship*	70	68.6%
Has children†	9	9.6%
Has bachelor's degree	94	86.2%
Has advanced degree (master's, doctorate, or professional degrees)	35	32.1%
Employed in past 6 mo‡	99	91.7%
Social occupation class		
Higher professional occupations	22	20.2%
Large employers, higher managerial and administrative occupations	7	6.4%
Lower managerial, administrative and professional occupations	35	32.1%
Intermediate occupations	14	12.8%
Small employers and own account workers	8	7.3%
Lower supervisory and technical occupations	4	3.7%
Semiroutine occupations	8	7.3%
Routine occupations	6	5.5%
Never worked or long-term unemployed	0	0.0%
Unemployed students	5	4.6%

n = 109 in the adulthood assessment.
*Current relationship status, *n* = 102.
†Parenthood status, *n* = 93.
‡Employment status, *n* = 108.

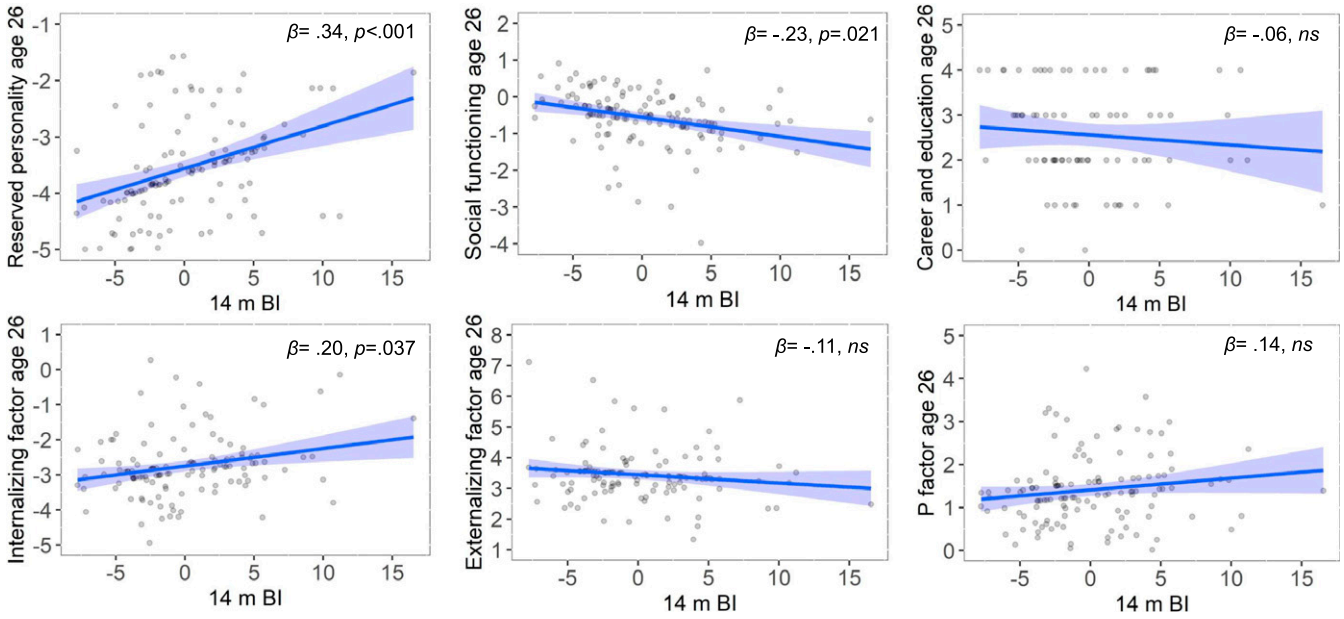

Fig. 2. The effect of 14-mo BI on reserved personality, social functioning, career and education outcomes, and psychopathology factors in adulthood (age 26). Shaded region denotes 95% CIs. ns, nonsignificant.

change between persons), rather than intraindividual differences (i.e., changes within a person in the same trait), across time. That is, highly inhibited infants still ranked higher on a reserved/introverted personality, internalizing psychopathology, and ranked lower on social functioning 25 y later, relative to less inhibited infants. Our findings extend prior longitudinal studies (11–13, 15–18) by showing the longest empirical evidence linking infant temperament with adult personality and by identifying the earliest age at which temperamental BI has predictive utility for multiple domains of functioning in adulthood. The reported prospective relation between an inhibited infant temperament and an introverted personality suggests that early temperamental qualities, which influence one's pattern of emotional, cognitive, and behavioral responses, might become embedded into a larger personality to shape various outcomes.

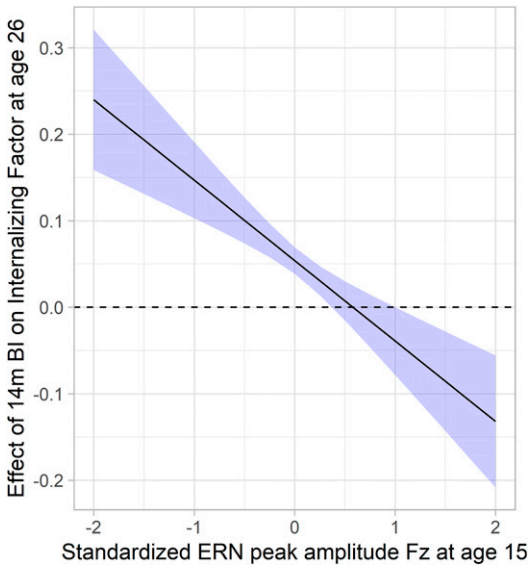

Fig. 3. Frontocentral (Fz) ERN peak amplitude as a moderator of the relation between 14-mo BI and internalizing psychopathology in adulthood (age 26). The *y* axis shows simple slopes for the effect of BI on the internalizing factor (higher values indicates stronger positive relations). This plot shows the region of significance, with the dotted horizontal line indicating a simple slope of zero and the shaded region indicating 95% CIs around estimates of slope. BI was a significant predictor of internalizing psychopathology among those with more negative amplitudes of the ERN (<0.75 *SD*), but not those with more positive amplitudes.

How is continuity between an inhibited infant temperament and a reserved adult personality preserved? Lifespan models of personality development assert that stability and change in personality are maintained by transactional processes (i.e., bidirectional interactions) between the individual, the environment, and random life events (33). Prior work emphasizes the role of two cooccurring developmental processes that connect early temperament to later personality: cumulative and interactional continuity (34). Cumulative continuity results from an accumulation of one's own predisposition. For example, BI children who are fearful and anxious of novel social interactions may choose to avoid peer interactions to relieve their anxiety, which in turn reduces opportunities for social learning and perpetuates social withdrawal as well as introversion (5). As people age, personality may become increasingly stable due to the accumulation of and reinforcement from consistent experiences selected or created by the individuals (35, 36). Unlike cumulative continuity, interactional continuity reflects the ways in which individuals evoke and receive responses in the environment in a reciprocal manner. For example, BI children may be raised by parents who tend to act in overprotective ways when BI children appear fearful. These parents may respond by restricting the child's autonomy in ways that reinforce the child's preexisting tendency to behave passively and withdraw from social interactions (5).

Second, we simultaneously tested specific and common psychopathology dimensions and integrated a neurophysiological measure into a predictive model to provide insight on psychological processes underlying different developmental pathways of BI infants. On a descriptive level, our results extend prior studies to show that infant BI specifically predicts internalizing (i.e., anxiety and depression), but not externalizing or general, psychopathology in adulthood. These lasting effects partially reflect the persistent course of childhood anxiety disorders,

which often remit and predict the onset of other anxiety and depressive disorders in young adulthood (19, 37). Incorporating neurophysiological measures, our results identify a subset of BI infants who manifest heightened error monitoring in adolescence and who face an increased risk for internalizing disorders in adulthood. This finding extends a previous report on this sample in adolescence, which showed enhanced error monitoring was concurrently associated with greater risk for clinical anxiety among BI children (31). Here, we further show that the combination of infant behavior and adolescent neurophysiology continued to predict internalizing psychopathology approximately a decade after the assessment of neurophysiology. Our findings also inform views on resilience, since a smaller ERN buffered against risk for internalizing psychopathology among those with higher BI. On a mechanistic level, increased error monitoring, indexed by a larger ERN, might reflect a rigid and "over-controlled" response pattern that hinders social interactions across development among temperamentally inhibited individuals (38, 39). This overrecruitment of the error monitoring system elucidates a maladaptive process associated with internalizing adolescent and adult psychopathology, which help explain different developmental trajectories from infant temperament.

Third, we found no evidence that infant BI predicted difficulties in education/career achievements or romantic relationships in adulthood. Mixed results on these outcomes have been reported in the extant literature (12, 13, 15, 16, 18), which might be attributed to methodological differences (e.g., measuring the timing versus occurrence of events) (13), or delays in adult activities (e.g., marriage, parenthood, investment in advanced education) (40) observed in recent generations that might mask potential effects of temperament. Alternatively, these null relations may indicate that although BI infants are at increased risk for internalizing psychopathology and worse social outcomes in some domains, they are by and large able to function effectively in society.

Our findings should be interpreted in light of study limitations. First, while we were able to detect some effects, our sample size was relatively small but comparable in size to prior longitudinal studies (e.g., in Asendorpf et al., $n = 96$) (13). The general effect sizes are small to moderate, but notable, considering that the observed effects span across 26 y, encompassing several stages of development beginning in infancy with the most biological, social, and cognitive changes. Second, the sample was homogenous in terms of ethnicity and family background, as the participants were primarily Caucasian who grew up in middle to upper-middle social classes, although social class in adulthood varied. Third, to mitigate the risk for type I errors, we reduced the dimensionality of the data using latent variable modeling whenever possible. However, multiple tests were conducted for social functioning and mental health outcomes, as such we further applied a false positive discovery rate to these two categories of outcomes. Adjusting for multiple tests, the interactive effects between the ERN and BI on internalizing psychopathology remained statistically significant (*SI Appendix*, Tables S11 and S12), although the main effects of BI on social functioning (*p-adjusted* = 0.053) and internalizing (*p-adjusted* = 0.111) did not (*SI Appendix*, Tables S8 and S10). Interpretation of statistical significance should balance risks for type I and type II errors, which are related to statistical power limitations resulting from a modest sample size. Furthermore, our a priori hypotheses were grounded in theory, prior empirical evidence, and were supported by our current findings. To ensure the generalizability of our findings, future studies with larger and ethnically diverse samples are needed.

In summary, strengths of this study include the application of 1) a life course perspective, 2) early behavioral observations of BI in infancy, 3) various assessments which reduced shared-method variance, and 4) latent constructs which maximized information from multiple scales and reduced the number of statistical tests. This study provided the earliest and strongest evidence of the impact of early infant temperament on adult personality and mental health. Finally, we identified neural processes that differentiate risk and resilient developmental pathways.

Materials and Methods

Participants. This prospective longitudinal study was designed to examine the influence of infant temperament on socioemotional development. One hundred and sixty-five infants ($n = 165$; 50.1% female) were recruited between the years 1989 and 1993 in the Washington, DC, metropolitan area. This sample is predominately Caucasian (98%), and the parents of the infants were in the middle to upper-middle class. Hospital birth records were used to obtain the mailing addresses of families with infants. Interested families completed a brief survey and were excluded if the infants were born preterm, showed any significant developmental problems or were on any long-term medications, and if either parent was left-handed.

BI was assessed at 14 mo (Mean [*M*] *age* = 14.58; SD = 0.06) using a behavioral observation paradigm. At age 15 y (*M age* = 15.05; SD = 0.82), 115 participants completed a variant of the flanker task (41) while electroencephalography (EEG) data were recorded and 94 participants had usable ERN after artifact rejection. At age 26 (range = 24–28; *M age* = 26.56; SD = 1.44), 109 participants (56.9% female) completed a series of self-report questionnaires remotely online via REDCap, a secure web application for data acquisition and storage (42). Among those who participated in adulthood compared to those who did not, there were no differences in BI at 14 mo ($P = 0.548$) or sex ($P = 0.366$), indicating that the final sample is representative of the original cohort.

Power analysis. To determine the minimum detectable effect sizes across the proposed analyses in our secured sample size, Monte Carlo simulation-based power analyses were performed in MPlus, version 8 (43). For each of the confirmatory factor analysis models with a covariate as the predictor of latent factors, 10,000 replications were drawn and sample size attrition (33% missingness for outcome measures at age 26) was taken into account. Results indicated that the secured sample size has a minimum power of 0.81 to detect standardized main effects of at least $\beta = 0.24$ between continuous measures of BI and latent outcome variables, and moderation effects of at least $\beta = 0.38$. Prior studies suggest that the main effect of inhibited temperament on adult outcomes is small to medium (0.11–0.42) (12). Similar-sized cohorts have reported relations between childhood temperament and adult outcomes ($n = 96$) (13).

Study procedures were approved by the University of Maryland Institutional Review Board. Participants provided consent for the assessment at age 26. For earlier assessments, consent was obtained from legal guardians and assent was obtained from participants.

Behavioral Inhibition (14 mo). BI was observed at 14 mo of age in the laboratory. Infants were exposed to three episodes, including a free-play session in an unfamiliar playroom, an adult stranger, and a novel toy robot (7). Infants' behaviors were videotaped and observers coded: 1) latency to first touch the toy during free-play, 2) latency to vocalize during free-play, 3) time spent in proximity within arm's length of the mother during free-play, 4) latency to vocalize to the stranger, 5) latency to approach the stranger, 6) time spent in proximity to the mother while the stranger presented the infant with a toy, 7) latency to vocalize to the robot, 8) latency to approach the robot, 9) time spent in proximity to mother during the robot episode. Intercoder reliability was computed for 15% of the sample. For each latency measure, correlations between two coders range from 0.85 to 1.00. To provide a measure of BI, scores were standardized and summed.

Flanker Task: Error-Related Negativity (15 y). At age 15, participants completed a letter version of a flanker task (41) while EEG was recorded (31). Each trial began with a cue (i.e., an asterisk) for 200 ms followed by a blank screen for 300 ms. Target displays of letters, which were either congruent (HHHHH or SSSSS) or incongruent (SSHSS or HHSHH), appeared for 250 ms. The intertrial interval randomly varied from 0 to 400 ms and responses were required within 1,100 ms after onset of the target. Participants were asked to identify the middle letter as quickly and accurately as possible using a button-box. The number of congruent and incongruent trials were equal, and hand-letter mappings were counterbalanced. Subsequent to completing a practice block with 20 trials, participants completed three experimental blocks (160 trials each), in which reaction time (RT) and accuracy were recorded. Response of omission, including trials with no response or

responses past the 1,100-ms window, were separately processed from trials with errors of commission. Additionally, trials with RTs ≤ 200 ms were excluded.

EEG recording and preprocessing. EEG was recorded from 15 sites (F3, F4, F7, F8, Fz, C3, C4, P3, P4, Pz, O1, O2, T7, and T8; Cz reference, AFz ground) positioned according to the international 10–20 system (44). Impedance was ≤ 10 kΩ. Electrooculogram (EOG) was recorded from two minielectrodes placed on the outer canthus and supra orbit above the right eye to monitor eye blinks. Both EEG and EOG channels were amplified by SA Instrumentation Bioamplifiers by factors of 5,000 and 1,000. The filter setting for all channels were set at 0.1 Hz (high pass) and 100 Hz (low pass). Data were digitized online at a sampling rate of 512 Hz with an Iotech Daqbook A/D converter.

EEG data were rereferenced offline with the average mastoid configuration and visually inspected for artifacts (e.g., eye blinks, body movements). Artifacts were edited out using software developed by the James Long Company. Epochs containing signals ± 200 μV were removed, and eye movement artifact was regressed. All channels were baseline corrected using a window (−150 to −50 ms) prior to response. All channels were digitally refiltered with a 15-Hz low-pass filter. EEG was time-locked to responses to create event-related potentials (ERPs) for correct and incorrect trials. Only errors of commission were classified as incorrect and were used to score the ERN.

The ERN is a mediofrontal negative deflection within 100 ms following an erroneous response (24). Waveforms, topography of the ERPs, and task effects are shown in *SI Appendix*, Fig. S1. A larger ERN compared to the correct-related negativity (CRN) was observed across peak and mean amplitudes, consistent with our prior report (31). We scored peak and mean amplitudes of the ERN between −20 and 200 ms, as well as difference scores (ERN minus CRN) at the frontocentral site (Fz) across congruent and incongruent trials (*M* number of trials = 47.02; SD = 35.96) and used these variables in further analyses. In sensitivity analyses, we isolated error-specific effects by examining the peak, mean, and difference scores of the ERN within incongruent trials only (*M* number of trials = 32.61; SD = 22.97).

Adult Reserved Personality (26 y). Shyness and sociability were reported using the Cheek and Buss Shyness and Sociability Scales (45). Items include, "I find it hard to talk to strangers" and "I feel nervous when speaking to someone in authority." Extraversion was reported in a subscale from the Revised Eysenck Personality Questionnaire (46). Items include "Do you like to talk a lot?" Internal consistencies for all questionnaires are displayed in *SI Appendix*, Table S1. The three measures were significantly correlated, *r* values = 0.57–0.73 (*SI Appendix*, Table S2) and used as indicators to measure a latent construct of reserved personality in further analyses.

Adult Social Functioning with Friends and Family (26 y). Functioning with friends and family were measured by separate subscales from the Adult Self-Report (ASR) (47). Items include number of close friends, how often they spend time with friends, and how well they get along with friends. Similarly, items for functioning with family include how often they spend time with family and how well they get along with each family member (e.g., parents, siblings, children). Additionally, the withdrawn subscale from the ASR (47) examined social withdrawal. The Satisfaction with Family Life Scale (48) measured global satisfaction of family life. Items include, "In most ways my family life is close to ideal." Social disconnectedness and feelings of loneliness were reported using the UCLA Loneliness Scale, version three (49). Items include "How often do you feel that you are 'in tune' with the people around you?" The Interpersonal Competency Scale (50) examined interpersonal effectiveness. Items included "If I want to, I can be a very persuasive person." The six variables were significantly correlated, *r* values = 0.23–0.65, except for the correlation between friend and family functioning which was not statistically significant although in the positive direction, *r* = 0.11, (*SI Appendix*, Table S2). The six variables were used as indicators to measure a latent construct of social functioning in further analyses.

Adult Romantic Relationship Outcomes (26 y). Marital and parenthood (i.e., having children) statuses were reported via individual items in the ASR (47). Current and history of romantic relationships were reported using the Course of Romantic Relationships Scale (51). Items include "number of romantic relationships in the past 10 years" and "are you currently in a relationship? (yes/no)."

Adult Education and Employment Outcomes (26 y). Participants reported their highest level of education, employment status in the past 6 mo (yes = 1; no = 0), and job titles and descriptions using the ASR (47). Job titles and descriptions were converted into standard occupation classification, a proxy of social class, using the National Statistics Socio-Economic Classification for government research in the United Kingdom (52). Possible scores range from 1 to 8 (1 = professional occupations or higher managerial, administrative roles; 8 = never worked and long-term unemployed). An additional category (9 = unemployed students) was created to classify students who were currently working toward a degree and currently unemployed (*n* = 5). Career satisfaction was reported using the Career Satisfaction Scale (53). Items include "I am satisfied with the progress I have made toward meeting my overall career goals." These measures were significantly correlated with each other, *r* values = 0.24–0.40, but not with employment in the past 6 mo as the majority of the sample (91.7%) was employed (*SI Appendix*, Table S3). A median split was applied to the continuous scales of education level, standard occupation classifications, and career satisfaction to create dichotomous variables (1 = high; 0 = low). A linear combination was created by summing the four variables to produce a 5-point scale (range = 0–4) and used in further analyses.

Adult Psychopathology (26 y). Social anxiety was reported using the Liebowitz Social Anxiety Scale (LSAS) (54). Items such as "participating in small groups" and "writing while being observed" capture fear and avoidance in social and performance situations. Anxiety symptoms within the past month were reported using the Beck Anxiety Inventory (BAI) (55). Items include "fear of losing control" and "hands trembling." Depressive symptoms were reported using the Beck Depressive Inventory-II (BDI) (56). Items include statements about specific symptoms, such as self-dislike. For example, "I feel the same about myself as ever," "I have lost confidence in myself," "I am disappointed in myself," and "I dislike myself." The ASR (47) further includes internalizing subscales, such as anxious-depressed behaviors, somatic symptoms, as well as externalizing behaviors, including subscales of aggression, attention problems, rule-breaking behaviors, and substance use. Internalizing measures were significantly correlated, *r* values = 0.41–0.80; Externalizing measures were significantly correlated *r* values = 0.25–0.71, with the exception that substance use and aggression were weakly correlated with each other, *r* = 0.15 (*SI Appendix*, Table S2).

Data Analyses. In preliminary data analyses, we first used confirmatory factor analyses (CFAs) to define three distinct sets of latent constructs measuring 1) reserved personality, 2) social functioning, and 3) psychopathology in adulthood. This approach maximized information from multiple measures, ensured the robustness and validity of latent constructs, and reduced the subsequent number of statistical tests. Subsequent to defining the outcome measures, we tested our hypotheses by adding predictors and regression paths to the latent outcomes in the main analyses. These structural equation model (SEM) analyses were performed in the R software package, "lavaan" (57). To determine model fit, we examined values of CFI, RMSEA, and SRMR, using the following conventional thresholds indicating good model fit: CFI ≥ 0.95, RMSEA ≤ 0.05, SRMR ≤ 0.08 (58).

Confirmatory factor analysis of reserved personality. Reserved personality was measured as a latent construct with three indicators, including scores from the shyness scale, sociability scale (reversed), and extraversion scale (reversed) (*SI Appendix*, Fig. S2). CFA of the measurement model revealed good fit (CFI = 1.00, RMSEA = 0.00, SRMR = 0.00). Model fit and factor loadings are shown in *SI Appendix*, Table S4.

Confirmatory factor analysis of social functioning with friends and family. Social functioning was measured as a latent construct with six indicators, including scores from the UCLA loneliness scale (reversed), ASR withdrawn scale (reversed), ASR friend functioning, ASR family functioning, satisfaction with family life scale, and interpersonal competence scale. CFA of the measurement model revealed poor fit (CFI = 0.87, RMSEA = 0.13, SRMR = 0.07). Based on modification indices, we allowed residual covariances between satisfaction with family life and family functioning, resulting in good model fit (CFI = 1.00, RMSEA = 0.00, SRMR = 0.03; *SI Appendix*, Fig. S3). Model fit and factor loadings are shown in *SI Appendix*, Table S5.

Confirmatory factor analysis of psychopathology. The structure of psychopathology was assessed using CFAs. Accumulating evidence suggests that a latent general psychopathology ("P") factor underlies commonalities across various disorder spectra, and specific internalizing and externalizing factors underlie unique features (or residual influences) that do not overlap with the P factor (20–22). First, we tested a correlated factors model, in which the two latent factors, 1) internalizing and 2) externalizing, were allowed to covary (*SI Appendix*, Fig. S4). Scores of the LSAS, BAI, BDI, and anxious/depressed and somatic complaints subscales from the ASR loaded onto the internalizing factor, whereas scores of substance use, attention problems, rule-breaking, and aggressive subscales from the ASR loaded onto the externalizing factor. Second, we tested a bifactor model, which expanded on

the correlated factors model to include a third general psychopathology factor with loadings from all scales to account for comorbidity across externalizing and internalizing domains of psychopathology (*SI Appendix*, Fig. S4). In the bifactor model, the covariances among the latent general psychopathology, externalizing, and internalizing factors were fixed to zero to reflect orthogonal concepts. Model fit and factor loadings of the correlated factors model and bifactor model are displayed in *SI Appendix*, Table S6. The corelated factors model showed poor fit (CFI = 0.78, RMSEA = 0.17, SRMR = 0.09); in contrast, the bifactor model showed good fit (CFI = 1.00, RMSEA = < 0.01, SRMR = 0.03). Also, a χ^2 difference tests ($\Delta\chi^2$) comparing the fit of the two models showed that the bifactor model better represented the data, $\Delta\chi^2$ (8) = 112.68, $P < 0.001$. Thus, the bifactor model was used in further analyses.

Main analyses. To test the first aim—examining the effect of infant BI on adult outcomes—BI was added into each CFA as the predictor of each of the latent adult outcomes (i.e., personality, interpersonal functioning, and psychopathology). For observed outcome variables (i.e., romantic relationship outcomes and education/career outcomes), these variables were regressed on BI in path models. To test the second aim—evaluating the moderating role of ERN on the relation between infant BI and adult psychopathology—the general psychopathology, externalizing and internalizing latent factors were regressed on BI, frontocentral ERN peak amplitude, and their interaction term. Predictors were mean-centered before generating the interaction term. Full information maximum likelihood estimation (FIML) was used to handle missing data. This estimation reduces potential bias in parameter estimates due to missing data and uses all available data in the analysis (59). Robust SEs (MLR) were used to correct for potential skewness and kurtosis in our variables (60). For path analyses involving binary outcomes, we used weighted least square mean and variance adjusted estimation (WLSMV) (61) in MPlus, version 8.

Sensitivity analyses. To test whether variation in how the ERN is quantified and whether task difficulty influence the results, we repeated the moderation analyses using 1) mean amplitude of the ERN and difference scores (ERN minus CRN), and 2) isolated error-specific effects using incongruent trials only.

In all analyses, we accounted for sex and age at the adulthood assessment. In the model examining education and career outcomes, we further accounted for intelligence quotient (IQ) collected between 15 and 18 y. IQ was assessed by trained examiners using Wechsler Abbreviated Scale of Intelligence (62). Multiple tests were performed for social functioning and mental health outcomes. To correct for inflation in type 1 error rate for these two groups of outcomes, we applied a 0.05 false positive discovery rate (63). The adjusted *P* values are shown in *SI Appendix*, Tables S8 and S10–S12.

Data Availability. Data and materials in this study are available on Open Science, https://osf.io/t7up3/.

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