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Longitudinal stability of temperamental exuberance and social-emotional outcomes in early childhood

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Abstract

The goals of the current study were to investigate the stability of temperamental exuberance across infancy and toddlerhood and to examine the associations between exuberance and social-emotional outcomes in early childhood. The sample consisted of 291 4-month-olds followed at 9, 24, and 36 months, and again at 5 years of age. Behavioral measures of exuberance were collected at 9, 24, and 36 months. At 36 months, frontal EEG asymmetry was assessed. At 5 years, maternal reports of temperament and behavior problems were collected, as well as observational measures of social behavior during an interaction with an unfamiliar peer in the laboratory. Latent profile analysis revealed a high, stable exuberance profile, which was associated with greater 5-year externalizing behavior and surgency, as well as disruptive behavior and social competence with unfamiliar peers. These associations were particularly true for children who displayed left frontal EEG asymmetry. Multiple factors supported an approach bias for exuberant temperament, but did not differentiate between adaptive and maladaptive social-emotional outcomes at 5 years of age.

Keywords

Development; Temperament; Longitudinal; EEG Asymmetry; Behavior Problems; Social-Emotional Outcomes

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Positive reactivity to novelty is a temperamental construct associated with approach behavior and related to child social-emotional outcomes. Infants who display positive affect and motor reactivity to novel stimuli are more likely to show uninhibited, exuberant, and sociable behavior in infancy (Hane, Fox, Henderson, & Marshall, 2008; Putnam & Stifter, 2002) and toddlerhood (Calkins, Fox, & Marshall, 1996; Fox, Henderson, Rubin, Calkins, & Schmidt, 2001; Park, Belsky, Putnam, & Crnic, 1997; Putnam & Stifter, 2005). In addition, a combination of high positive affect and approach behavior is associated with impulsivity, positivity, and sociability in childhood (Fox et al., 2001; Pfeifer, Goldsmith, Davidson, & Rickman, 2002; Stifter, Putnam, & Jahromi, 2008). Together, positive reactivity, approach, and sociability, define the broad construct of temperamental exuberance (Putnam & Stifter, 2005; Pfeifer et al., 2002; Rothbart, Ahadi, Hershey, & Fisher, 2001).

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From a motivational systems perspective, exuberance is likely supported by an underlying motivation to approach, which guides individual levels of positive reactivity (Fox, 1991; Gray, 1982). This motivational tendency may be represented by distinct neural profiles, indices of which can be found in patterns of left frontal EEG asymmetry (Fox, 1994). This continuation in positive approach across both behavioral and biological levels may be associated with adaptive, sociable behavior. However, if children do not develop methods of regulating their approach, they may display more oppositional or externalizing behavior problems (Polak-Toste & Gunnar, 2006; Stifter et al., 2008).

Historically, the field of child temperament has focused on children's problematic behaviors, linked with negative reactivity to frustration- or fear-eliciting events and stimuli (Rothbart & Bates, 2006). However, there has been a recent interest in the development of positive affect and temperamental exuberance (Dennis, 2006; Rydell, Thorell, & Bohlin, 2007; Stifter et al., 2008). Though exuberance is associated with low levels of both behavioral inhibition and social wariness (i.e., uninhibited behavior, Fox et al., 2001), there is evidence to suggest that these approach biases represent an orthogonal, independent temperamental construct (Dennis, 2006; Laptook, Klein, Durbin, Hayden, Olino & Carlson, 2008; Pfeifer et al., 2002), associated with distinct outcomes. Therefore, the current study examined patterns of exuberance across early childhood, as well as the role of frontal EEG asymmetry in differentiating adaptive and maladaptive social-emotional outcomes for high exuberant children.

Definition of the construct

Recently, exuberance has been put forth as a temperamental construct worthy of empirical investigation. It has been operationalized in multiple ways, but is thought to be supported by an overall motivational state linked to reward sensitivity and expectancies (Polak-Toste & Gunnar, 2006). While there is some debate as to which neural systems are implicated, positive reactivity and approach tendencies likely stem from heightened activation of the behavioral activation system (BAS), lower activation of the behavioral inhibition system (BIS), or systems that support the anticipation and saliency of rewarding stimuli (Depue & Collins, 1999; Gray & McNaughton, 2000; Panksepp, 1998; Zuckerman, 1991). Specifically, Gray's (1982) motivational view of temperament suggests that heightened BAS activity leads to greater conditioned approach and impulsivity. In addition, Depue's and Collins' (1999) behavioral facilitation system (BFS) model suggests that dopaminergic projections to neural sites involved in encoding the salience of reward stimuli are implicated in individual differences in approach behavior. Therefore, individuals with heightened reactivity of the BAS and/or BFS may be quick to approach and experience greater positive affect in response to reward (Depue & Collins, 1999; Polak-Toste & Gunnar, 2006). It is these tendencies that are believed to support an exuberant style of temperament.

In the developmental literature, terms such as positive affectivity, surgency, extraversion, approach reactivity, impulsivity, and sensitivity to reward are often used to describe exuberant temperament (Polak-Toste & Gunnar, 2006; Rothabart & Bates, 2006). Fox and colleagues observed a subset of their infant sample as approaching novelty and enjoying social interaction, and suggested links to fearlessness, risk-taking, and social competence (Fox et al., 2001; Hane et al., 2008). Goldsmith and colleagues described their childhood sample in terms of increased positive affect and a heightened, fearless approach to novel stimuli (Pfeifer et al., 2002). In general, the combination of positive affect and approach behavior have been posited as the core, distinguishing factors involved in exuberance, surgency, or extraversion (Putnam & Stifter 2005; Rothbart et al., 2001; Watson & Clark, 1997).

There are clear distinctions between the temperaments of behavioral inhibition and exuberance. For instance, one study examining measures of both behavioral inhibition and exuberance across childhood showed non-linear relations between them, where high exuberance was predicted by average levels, as opposed to low levels, of behavioral inhibition (Pfiefer et al., 2002). In addition, Putnam and Stifter (2005) described multiple types of behavior, based on levels of approach and positive or negative affect, where low approach combined with negative affect reflected behavioral inhibition and high approach combined with positive affect reflected exuberance. These profiles were also distinguished by latency to touch novel toys throughout infancy and concurrent behavior problems (Putnam & Stifter, 2005). Furthermore, work has shown that behavioral inhibition or low approach behavior is present when negative affect is high, but there is little positive affect present (Laptook et al., 2008; Park et al., 1997). Thus, the combination of positive affect and approach seems to define exuberant behavior. In addition, while positive affect emerges early and has been observed to display stability across infancy, increased wariness or low approach to novelty may not emerge until 8 months of age (Putnam & Stifter, 2002) and is observed to display both stability and instability across toddlerhood and childhood (Degnan & Fox, 2007), suggesting separate developmental patterns for behavioral inhibition and exuberance.

Developmental studies suggest high continuity of exuberance within measurement type, and moderate continuity between measurement types, across infancy and across childhood (Majdandz¡ic´ & van den Boom, 2007; Stifter et al., 2008). Specifically, high levels of continuity have been reported for observed exuberance or uninhibited behavior (Fox et al., 2001; Putnam & Stifter, 2002). There also is support for moderate stability in parent-report of positive affect across infancy and toddlerhood (Rothbart, 1986) and approach/sociability between infancy and middle childhood (Pedlow, Sanson, Prior, & Oberklaid, 1993). Furthermore, Rothbart and colleagues (2001) found strong associations between parent-reported positive affect in infancy and approach motivation in middle childhood. This work suggests the behaviors that underlie exuberance represent a rather stable temperament construct. However, there are few studies that have specifically examined the longitudinal continuity of exuberance, using behavioral measures, across both infancy and toddlerhood.

Outcomes of exuberance

Overall, exuberance reflects a strong motivation to approach, especially in the presence of novelty, combined with a tendency for heightened positive affect. These positive approach tendencies are thought to be supported by biological systems linked to both an underlying motivational bias to approach (Gray, 1982), as well as a reactive reward-approach system (Depue & Collins, 1999). However, in relation to outcomes, there are multiple ways approach behavior might be manifest. Consistent with the motivational framework, individuals with a heightened approach system would display greater positive affect and approach toward novel social stimuli in the form of positive sociability. In essence, they would revel in these social situations (Fox et al., 2001). Another viewpoint, supported by Depue & Collins’ (1999) reactive BFS model, suggests that positive approach would only occur when one’s goals are not being blocked. In turn, when these individuals’ goals are blocked, they would respond with greater frustration and potentially aggressive behavior toward the source of the blockage. Thus, high levels of approach and positive reactivity to reward or novelty (i.e., exuberance) may lead to both socially adaptive and maladaptive outcomes.

Indeed across empirical studies, exuberance and its associated factors of positivity and approach are related to both adaptive and maladaptive social-emotional outcomes. For example, two separate research programs have reported that parent-rated positive affect in elementary school children was related to greater externalizing behavior problems

(Eisenberg, Fabes, Guthrie, Murphy, Poulin, & Shepard, 1996; Rothbart, Ahadi, & Hershey, 1994). Observed exuberance, or positive reactivity to novelty, in infancy or toddlerhood has been related to greater maternal-reported anger (Calkins et al., 1996), observed anger during an arm restraint task (He, Degnan, Hane, Henderson, Xu & Fox, 2009), observed frustration during two emotionally challenging tasks (Dennis, 2006), and parent-report of externalizing problems (Putnam & Stifter, 2005; Stifter et al., 2008) in toddlerhood and preschool. Similarly, teacher ratings of surgency have been associated with greater peer ratings of girls' "wild behavior" in kindergarten (Berdan, Keane, & Calkins, 2008). Furthermore, studies of disinhibition (i.e., novelty-seeking and impulsivity) have found associations with externalizing/antisocial diagnoses (Hirshfeld-Becker, Biederman, Faraone, Violette, Wrightsman & Rosenbaum, 2002; Hirshfeld-Becker, Biederman, Henin, Faraone, Cayton & Rosenbaum, 2006; Hirshfeld-Becker et al., 2007).

However, there is also evidence that exuberance, or positive reactivity, is associated with adaptive outcomes. Caspi and Silva (1995) reported that an outgoing, "confident" group of preschool children displayed less behavioral control, but greater social potency at 18 years of age and again in adulthood (Caspi, Harrington, Milne, Amell, Theodore & Moffitt, 2003). An important factor for this "confident" group, as opposed to a similar "undercontrolled" group that showed more maladaptive outcomes, was the expression of high levels of positive affect by the "confident" group during the preschool assessment (Caspi et al., 2003; Caspi & Silva, 1995). Indeed, positive reactive infants have shown greater joy and sociability in infancy and childhood (Fox et al., 2001; Hane et al., 2008) and exuberant children have shown greater organized (i.e., appropriate and productive) emotion regulation behaviors (Dennis, Hong & Solomon, in press; Rydell et al., 2007). In addition, studies with adolescents have shown extraversion to be positively associated with greater self-esteem and teacher-reported social competence (Davey et al., 2003; Graziano & Ward, 1992).

Somewhat limited in this literature is an examination of both externalizing and internalizing types of behaviors. In addition, most behavioral outcomes in these studies have been reported by adults or peers in the classroom. A more thorough investigation of observed social behavior with peers during structured interactions is needed in order to decipher the specific outcomes for children with an exuberant temperament. For example, social competence can be measured in multiple ways. In childhood, behaviors such as displaying positive affect, being socially engaged with peers, and attempting social problem solving would fall under this rubric. However, behaviors such as displaying negative affect, being uninvolved or unoccupied during structured peer activities, and acting aggressively toward others would be considered socially incompetent. Moreover, a multi-informant, multi-measure approach would help distinguish between adult perceived behavior and observed social behavior.

Frontal EEG asymmetry

One factor that may influence continuity in exuberance overtime is frontal EEG asymmetry. Stemming from Gray's (1982) motivational systems theory, Davidson (1995) suggested that the pattern of frontal EEG asymmetry might reflect an underlying motivational bias to respond to the environment in a particular manner. In general, motivation to withdrawal has been associated with resting right frontal asymmetry, while resting left frontal asymmetry has been associated with approach-related behavior (Davidson, 1994). Therefore, if left asymmetry is a biomarker of approach, then children who show coherence between their electrophysiological profile of left FA and an early behavioral profile of approach and positivity may display a persistent pattern of temperamental exuberance across early childhood, including sustained positive affect in response to novelty and high sociability in peer interactions.

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Davidson and Fox (1989) examined whether differences in EEG asymmetry are markers for individual differences in emotionality in infancy and argued that infants who show a characteristic left-sided frontal EEG asymmetry may be more likely to display positive affect. While much of this work has focused on differences among behaviorally inhibited children, infants who are positively reactive to novelty have been shown to exhibit greater relative left frontal activation (Calkins et al., 1996; Fox et al., 2001; Hane et al., 2008).

Since greater left frontal EEG asymmetry has been linked to higher levels of positive reactivity, it should be implicated in temperamental exuberance. However, asymmetry may also be one mechanism influencing the continuity of temperamental exuberance over time (Coan & Allen, 2004). This idea is supported by evidence for the indirect effects of left frontal EEG asymmetry on the discontinuity in behavioral inhibition (Degnan & Fox, 2007). A study examining the relations between negative reactivity at 9-months of age and social wariness at 4-years of age found that frontal asymmetry moderated the relation between infant temperament and later social behavior. Specifically, negative reactivity predicted later wariness but only when children displayed right frontal EEG asymmetry at 9-months of age (Henderson, Fox, & Rubin, 2001). When children showed left frontal EEG asymmetry as infants, their negative reactivity in infancy did not correlate with their level of social wariness in preschool. Given that left frontal EEG asymmetry has been linked to approach, positive affect, and sociability (Fox, 1991), this characteristic may influence the development of stable approach tendencies (i.e., exuberance). Therefore, the current study examined left frontal EEG asymmetry in toddlerhood as a biomarker for approach motivation. Specifically, this measure of asymmetry was examined in order to explore whether a proximal approach-related neural profile was associated with a pattern of exuberance over time and whether it supported a particular pattern of social behavior later in early childhood.

Current Study

The first goal of the current study was to explore the longitudinal stability of exuberance, including positive affect, approach behavior, and sociability, across infancy and toddlerhood. Supported by the motivation systems perspective of temperament (Gray, 1982), positive affect and approach behavior, especially towards novel or social stimuli, have been associated with a general motivational bias to approach. In addition, previous work suggests that these factors are inter-related and subsumed under the rubric of temperamental exuberance (Polak-Toste & Gunnar, 2006; Putnam & Stifter, 2005), although there are a limited number of studies that have used detailed examinations of all of these behaviors. Furthermore, previous work has found a high level of stability in exuberant reactions over childhood (Fox et al., 2001; Majdandz¡ic´ & van den Boom, 2007). Therefore, it was expected that a subset of children would display a high, stable exuberance profile.

The second goal of the study was to examine the relations between high, stable exuberance and social-emotional outcomes at 5 years of age. Throughout the literature, there are multiple ways positive approach behavior might be displayed. Consistent with the motivational framework, individuals with a heightened approach system would display greater positive affect and approach toward novel social stimuli (Fox et al., 2001). However, another viewpoint suggests that positive approach would only occur when one’s goals are not being blocked. Hence, when goals are blocked, individuals would display frustration and aggressive behavior (Depue & Collins, 1999). In addition, empirical studies have found infants who display positive affect and an approach-driven motivational bias show high levels of positive affect and sociability (Hane et al., 2008), but are also rated higher on caregiver-reports of externalizing problems (e.g., Stifter et al., 2008). Thus, it was expected that the high, stable exuberance profile would relate to both adaptive (e.g., social engagement and competence) and maladaptive (e.g., externalizing behavior problems) functioning at later ages.

Furthermore, resting frontal EEG asymmetry at 36 months was examined as a potential moderator of the associations between exuberance and behavioral outcomes. The motivation-direction hypothesis suggests that motivation to withdrawal or approach is associated with differences of asymmetries in resting frontal EEG activity (Davidson, 1994). Specifically, the continuation of positive approach tendencies is thought to be supported by the neural mechanisms underlying left frontal EEG asymmetry. Therefore, the combination of an exuberant temperament and an underlying motivational bias for approach would be associated with greater sociability. However, this combination of temperament and neural bias may also predict externalizing behavior problems if methods of regulating this approach behavior fail. Furthermore, EEG asymmetry at 36 months was utilized in order to examine the level of motivational bias coexistent or proximal to the enduring patterns of temperamental exuberance in late toddlerhood, as these neural profiles could potentially change with development.

Methods

Participants

As part of a longitudinal study conducted in a large metropolitan area of the mid-atlantic region of the United States, families were contacted by mail and screened by phone to ensure that infants were born full-term, had not experienced any serious illnesses or problems in development thus far, and were not on any long-term medication. Seven hundred and seventy-nine infants who met these criteria were brought into the laboratory at 4 months of age for an additional temperament screening, during which affect (positive and negative) and motor reactivity during the presentation of novel visual and auditory stimuli were observed (for more details, See Hane et al., 2008). Two hundred and ninety-one infants (135 males, 156 females) were selected based on their classification into one of three different temperament groups: high negative/high motor reactive (n = 105); high positive/ high motor reactive (n = 103); and control group (n = 83) that was below the cutoffs on negative/positive/motor reactivity. Of these infants, 187 (64.3 %) were Caucasian, 41(14.1%) were African American, and 63 (21.5%) were of other ethnicity. At the outset of the study, the majority of families spoke English at home, although approximately 2% spoke at least one additional language in the home (i.e., Spanish, Indian, Russian, or Chinese). Information regarding family income was not collected, however, most mothers were at least college educated (84.4 %) and the others (15.6%) had at least a high school education.

Procedures

Following the temperament screening at 4 months of age, infants were assessed at 9, 24, and 36 months, as well as 5 years of age. When the infants were 9 months, their behavioral and affective reactivity were assessed during a number of emotion-eliciting paradigms adapted from the Laboratory Temperament Assessment Battery (Lab-TAB; Goldsmith & Rothbart, 1999). At 24 and 36 months, behavior and affect were observed during behavioral inhibition (Fox et al., 2001) and risk-taking (Kochanska, 1995; Peifer et al., 2002; Putnam & Stifter, 2005) paradigms. At 5 years, children were brought to the laboratory for a peer dyad assessment that included free-play, cleanup, and social problem-solving tasks, and mothers completed a series of questionnaires about their child's behavior and temperament.

Measures

Positive Approach—At 9 months of age, a number of tasks from the Lab-TAB assessment (Prelocomotor version 3.1; Goldsmith & Rothbart, 1999) were administered, including masks, unpredictable toy, puppets, and peek-a-boo. All were carried out in accordance with Lab-TAB guidelines (for more details, see Hane, Fox, Polak-Toste, Ghera, Gunner, & Fox, 2006). Video recordings of the assessment were coded in epochs for aspects of positive affect and approach behavior. Specifically, intensity of smiling (0–2), intensity of positive motor behavior (0–2), and latency to display joy (reverse-scored; in seconds) were recorded during the puppets and peek-a-boo episodes, in addition to the intensity of approach behavior (0–3) and duration of attention towards the puppets (in seconds). For the toy and mask episodes, intensity of positive affect (0–3), intensity of positive motor behavior (0–2), and presence of approach towards the stimuli (0, 1) were recorded. Inter-rater reliability was achieved by two independent observers who were blind to all other data in the study. Reliabilities across 20% of the cases were achieved separately for each of the scales during each episode. Kappas ranged from .75 to .92 (M = .85) for the puppets codes; .81 to .84 (M = .83) for the peek-a-boo codes; .59 to .98 (M = .78) for the unpredictable toy codes; and .76 to .97 (M = .85) for the masks codes. Intra-class correlations (ICCs) computed for latency to joy during puppets (r = .93) and peek-a-boo (r = .84), as well as duration of attention to the puppets (r = .97) showed good inter-rater reliability.

All codes were standardized and averaged across epochs, within task and subsequently averaged across tasks to create a measure of *Positive Approach* (M = −.03, SD = .49; α = .64). While the puppets and peek-a-boo episodes were designed to elicit joy and approach and the toy and mask episodes were designed to elicit fear and withdrawal, some infants displayed positive affect and approach behavior during the toy and mask episodes. Therefore, behavior and affect across all four tasks were included so that higher scores on the composite score reflected a more extreme level of positive approach during both positive and negative emotion-eliciting stimuli.

Exuberance—At 24 and 36 months of age, children were assessed for exuberant affect and behavior during the standard behavioral inhibition paradigm (Fox et al., 2001; Kagan, Reznick, & Snidman, 1987), as well as an exuberance/risk-taking paradigm (Kochanska, 1995; Pfeifer et al., 2002; Putnam & Stifter, 2005). The behavioral inhibition paradigm tasks were presented separately in a specified order, while the exuberance/risk-taking task stimuli were spread out across the playroom floor. At both time points, the behavioral inhibition paradigm included a freeplay task, a stranger approach task, a robot task, and a tunnel task (for more details, see Fox et al., 2001). At 24 months, the exuberance/risk-taking tasks included a black box the child was asked to stick their hand into, climbing up steps to jump onto a mattress, watch a confetti popper, and approach a vacuum cleaner. At 36 months, the exuberance/risk-taking tasks included putting on a blood pressure cuff, jumping on a trampoline, touching a gorilla mask, climbing up steps towards the wall, touching a realistic-looking snake, touching an unpredictable mechanical dragon toy, and sitting close to the experimenter to read a book.

At each age, in the order listed above, the experimenter requested that the child approach or perform each task. If the child did not approach, the experimenter was permitted to prompt the child. Once the child approached/performed the task, or it was clear that the child was refusing to participate, the experimenter requested that the child go on to the next set of stimuli. Throughout the risk-taking episodes, the experimenter maintained a neutral tone, except while reading the book at 36 months, when the experimenter was permitted to try and engage the child as much as possible. Each task was coded (in seconds) for latencies to touch/approach the stimuli, latency to vocalize, proportion of time spent in proximity to mom, proportion of time spent in proximity to experimenter, number of experimenter prompts, activity level (range: 0–3), and degree of approach towards stimuli (range: 0–3). Inter-rater reliability (ICCs across 20% of the cases) for these continuous measures ranged from .78 to .98 (M = .87). Each task was also coded in 30-second epochs for the presence of smiling, positive vocalizations, talking to experimenter, smiling at experimenter, gesturing to experimenter, verbal initiations to experimenter, and willingness to perform each task. Inter-rater reliability (kappas) for these measures ranged from .60 to .82 (*M* = .70).

All scores were standardized and averaged across task. Average scores which were highly skewed were dichotomized where 0 = not present and 1 = present. Average codes were then combined into three subscales at each age: Positivity, Approach, and Sociability. Positivity and Approach subscales were designed based on the work by Stifter and colleagues (e.g., Putnam & Stifter, 2005) and the Sociability subscale was added as a unique part of the current study. The Positivity subscale included smiling and positive vocalizations (24-month α = .74; 36-month α = .81). The Approach subscale included latencies to touch/approach the stimuli (reverse-scored), proximity to mother (reverse-scored), latency to vocalize (reverse-scored), activity level, number of prompts (reverse-scored), degree of approach, and willingness to perform each task (24-month α = .63; 36-month α = .83). The Sociability subscale included all of the codes with reference to the experimenter, specifically: proximity, talking, smiling, gesturing, and verbal initiations (24-month α = .79; 36-month α = .86). Finally, an overall *Exuberance* subscale was computed at each age as the average of the positivity, approach, and sociability subscales (24-month: *M* = .10, *SD* = .30, α = .79, inter-correlations: .44 – .66; 36-month: *M* = .10, *SD* = .29, α = .71, inter-correlations: .24 – .57).

Electroencephalogram (EEG) Asymmetry—At 36 months of age, frontal EEG asymmetry was assessed during a baseline task for a total of 2 minutes. During the collection of EEG, children were asked to sit quietly and were read a book by the experimenter. While the child was quietly attending to the book, EEG was collected during four 30-second epochs – two epochs while the room was illuminated and two epochs while the room was darkened. In addition, glow-in-the-dark stars were pasted on the wall facing the child to distract them from the darkness of the room. Epochs alternated between light and dark conditions.

Prior to EEG collection, the toddler was fitted with a Lycra stretch cap (Electro-Cap International Inc., Eaton, OH) containing electrodes according to the 10–20 system of electrode placement. EEG was recorded from 14 scalp sites (F3, F4, F7, F8, Fz, C3, C4, P3, P4, Pz, O1, O2, T7 and T8) and two mastoid sites (A1 and A2). An anterior midline site (Afz) served as the ground electrode and the EEG was collected referenced to the vertex (Cz). The scalp underlying each electrode site was gently abraded and electrolytic gel was inserted into the space between the scalp and the electrode. Impedances were considered acceptable if they were at or below 10 kΩ. The EEG data was digitized at a rate of 512 Hz using a 12-bit A/D converter (± 2.5 V input range) and Snap-Master acquisition software (HEM Data Corporation, Southfield, MI). The EEG signal was amplified by a factor of 5000 using custom bioelectric amplifiers (SA Instrumentation, San Diego, CA). The high-pass and low-pass filter settings were 0.1 Hz and 100 Hz, respectively. A 50 μV 10 Hz signal was recorded from each channel and used for calibration purposes. All further processing was carried out using the EEG Analysis System from James Long Company (Caroga Lake, NY).

EEG channels were re-referenced to an average-mastoids reference. EOG was recorded from the left eye using two Beckman mini-electrodes. Data were displayed graphically for artifact scoring and portions of the EEG that exceeded 225 μV were excluded from analysis. A significant number of infants with otherwise usable EEG data had poor quality or no EOG signal. For those infants with good EOG data, EOG-EEG propagation factors were computed and found to be of very small magnitude, indicating that the eyeblinks had a limited effect on the EEG signal, including the frontal leads. Therefore, EOG data were not used in further analysis or processing.

EEG was analyzed with discrete Fourier transform (DFT) analysis using a 1-second Hanning window with 50% overlap. The power in picowatt ohms (or microvolts squared) was computed for each site. Spectral power data in single-hertz frequency bins from 1–30 Hz were computed for each of the epochs at each electrode site. Power in the 6–9 Hz alpha-range band was calculated for each site by summing the power in the single hertz bands of these four frequencies across trials. The power data in the 6–9 Hz band was then log-transformed at frontal and parietal regions (F3 and F4, P3 and P4) and the asymmetry score was computed as power in the right hemisphere minus power in the left hemisphere (M = .01, SD = .19). Infants who had insufficient EEG data (less than 30 sec of artifact-free data) or had asymmetry scores that were outside of a ± 1.00 range were excluded as outliers (n = 4). This final *Asymmetry score* was normally distributed (*M* = .02, *SD* = .13). Since power is reciprocally related to activation, positive scores reflected left asymmetry, and negative scores reflected right asymmetry.

5-year outcomes: Maternal report

Child Behavior Checklist (CBCL 1.5–5; Achenbach & Rescorla, 2000)—The CBCL was used to assess child behavior problems at 5 years of age. Mothers used a 3-point scale to rate how often their children displayed a series of behavior problems, with 0 = never, 1 = sometimes, and 2 = often. The CBCL is reduced to two broad-band factors, externalizing behaviors (i.e., physically attacks people) and internalizing behaviors (i.e., unhappy, sad, or depressed). These scores have shown internal consistency and moderate stability across a 12-month period of time (for details, see Achenbach & Rescorla, 2000). As Achenbach and Rescorla (2000) have suggested for developmental research, the raw scores were used in the present study. *Externalizing* scores ranged from 0 to 30 (*M* = 8.89, *SD* = 6.60). *Internalizing* scores ranged from 0 to 20 (*M* = 6.24, *SD* = 4.90).

Child Behavior Questionnaire (CBQ; Rothbart et al., 2001)—The CBQ was used as a measure of child temperament at 5 years of age. Mothers responded to whether 195-items were true about their child (rated from 1 = extremely untrue to 7 = extremely true). These items then form several dimensions that can be reduced to 3 broad factors (Rothbart et al., 1994): Surgency, Negative Affect, and Effortful Control. Surgency (*M* = 4.58, *SD* = .63) includes the dimensions of activity level, high-intensity pleasure, impulsivity, and shyness (reverse-scored). Negative Affect (*M* = 3.89, *SD* = .70) includes the dimensions of anger, discomfort, fear, sadness, and soothability (reverse-scored). Effortful Control (*M* = 5.31, *SD* = .55) includes the dimensions of attention focusing, inhibitory control, low-intensity pleasure, and perceptual sensitivity.

Colorado Child Temperament Inventory (CCTI; Rowe & Plomin, 1977)—The CCTI was used as a measure of child temperament at 5 years of age. Mothers responded to whether 30 items described their child (rated from 1 = unlike child to 5 = like child), which formed 6 subscales (Buss & Plomin, 1984). All subscales, including Emotionality (*M* = 2.59, *SD* = .75), Activity level (*M* = 3.93, *SD* = .65), Attention (*M* = 3.44, *SD* = .65), Soothability (*M* = 3.40, *SD* = .61), Shyness (*M* = 2.24, *SD* = .81), and Sociability (*M* = 3.78, *SD* = .61), were included in the present analysis. In addition, emotionality was subtracted from soothability to form a composite measure of Emotion Regulation (*M* = .82, *SD* = 1.15).

Maternal-report composites—Subscales of temperament from the CBQ and CCTI were standardized and aggregated to form broad measures of *Surgency*, *Negative Reactivity*, and *Regulation* at 5 years of age. Specifically, measures of CBQ Surgency, CCTI activity level, CCTI shyness (reversed-scored), and CCTI sociability were averaged to form the overall 5-year *Surgency* composite (*M* = .01, *SD* = .76; α = .77; inter-correlations: .24 – .69). Measures of CBQ negative affect and CCTI emotion regulation (reverse-scored) were averaged to form the overall 5-year *Negative Reactivity* composite (*M* = .01, *SD* = .91; α = .78; *r* (222) = .64). Measures of CBQ effortful control and CCTI attention were averaged to form the overall 5-year *Regulation* composite (*M* = .00, *SD* = .84; α = .60; *r* (226) = .43). Measures of *Internalizing* and *Externalizing* from the CBCL were left as separate indices of behavior problems at 5 years.

5-year outcomes: Peer dyad

Children interacted with an unfamiliar peer in the laboratory during freeplay, cleanup, and special toy episodes at 5 years of age. Children were introduced in the hallway and then led into the playroom to begin the assessment. The interactions were videotaped through a one-way mirror for later behavioral coding and analysis. A team of coders was assigned to each episode and inter-rater reliability was achieved on at least 20% of each type of interaction prior to coding the remainder of the sample.

Freeplay episode—For this task, a broad range of age-appropriate toys were scattered across the floor and children were allowed to play for 10 minutes. Behavior was rated in 2-minute epochs for wariness, unfocused/unoccupied behavior, aggression, social interest, activity level, negative affect, and positive affect. Ratings ranged from 1 (none observed in epoch) to 7 (observed throughout epoch). Inter-rater reliability (ICCs) ranged from .73 to .94 (*M* = .82). Each code was averaged across epochs.

Cleanup episode—For this task, children were given 5 minutes to clean up the toys used in the freeplay episode. Coders assessed the duration of time (in seconds) spent cleaning up the toys, refusing to clean up the toys, and uninvolved in cleaning up the toys. Inter-rater reliability (ICCs) ranged from .90 to .97 (*M* = .93). For the current analyses, the proportion of time Unoccupied (*M* = .09, *SD* = .09) was created by dividing the amount of time (in seconds) uninvolved (not cleaning or refusing) by the total time given to clean up the toys.

Social Problem-Solving episode (Special Toy)—For this task, children were asked to share a portable, learning system (i.e., Leapster®), which they could use to independently play an educational phonics game. The children were allowed to play with the toy for a total of 5 minutes. Social initiations were coded based on schemes used by Rubin and Krasnor (1983) and Stewart and Rubin (1995).

An attempt to get the toy was coded when the child was not in possession of the toy and initiated an interaction in order to gain control and/or make it clear to the peer, that he or she wanted a turn. Attempts to get the toy were then classified by the goal of the initiation: Stop Action (explicit attempt to stop peer from using the toy), Agonistic (aggression directed at the peer), or Object Acquisition (socially assertive, but competent initiations). Each attempt was further classified by the type of strategy used to achieve the goal: Passive (e.g., pointing or hovering), Active (e.g., touching, hitting, or taking), or Verbal (e.g., asking or telling). Agreement between coders (ICCs) on identifying attempts to get the toy was .91. ICCs for social problem solving goals were.67 for stop action, .62 for agonistic, and .91 for object acquisition. ICCs for social problem solving strategies were .77 for Passive, .86 for Active, and .93 for Verbal strategies. Proportions of each goal and strategy classification were calculated by dividing the frequencies of each code by the total number of attempts to get the toy. Proportions of interest were object acquisition goals (*M* = .67, *SD* = .43), and Passive (*M* = .07, *SD* = .18), Active (*M* = .32, *SD* = .34), and Verbal (*M* = .36, *SD* = .35) strategies.

Social dyad composites—Measures from the freeplay (FP), cleanup (CL), and special toy (ST) episodes were standardized and averaged to represent *Social Reticence*, *Disruptive*

Behavior, and *Social Competence* at 5 years of age. All three composites were formed on a theoretical basis and confirmed by factor analysis. Specifically, *Social Reticence* was formed based on work by Rubin and colleagues (e.g., Fox, Henderson, Rubin et al., 2001) and consisted of FP Wariness, FP Unfocused/Unoccupied, CL proportion of time Unoccupied, and ST Passive strategies (M = −.03, SD = .62; Eigenvalue = 1.58, average loading = .62). Overall, the definitions of these scores were consistent with the construct of social reticence examined extensively by Rubin and colleagues (Rubin, Coplan, Fox, & Calkins, 1995), whereby children remain vigilant to the peer, but do not interact; remaining in an unoccupied, onlooking state. *Disruptive Behavior* was formed based on existing literature on behavior that would be considered disruptive and problematic in early childhood (e.g., Kopp, 1989; Campbell, 2006) and consisted of the average of FP Negative affect, FP Aggression, ST Active strategies, and ST verbal strategies – reverse scored (M = .01, SD = .61; Eigenvalue = 1.29, average loading = .52). *Social Competence* was formed to reflect positive sociable behavior that supported the goal of the individual tasks and consisted of the average of FP Social Interest, FP Positive affect, FP Activity level, ST positive affect, and ST proportion of object acquisition goals (M = .00, SD = .62; Eigenvalue = 1.81, average loading = .52).

Summary of Measures

In the present study, measures of temperamental exuberance included temperamental reactivity group membership at 4 months, *Positive Approach* at 9 months, as well as *Positivity*, *Approach*, *Sociability*, and overall *Exuberance* at 24- and 36-months of age. Social-emotional outcome measures at 5 years included maternal report composites of *Internalizing behavior*, *Externalizing behavior*, *Surgency*, *Reactivity*, and *Regulation*, as well as observed behavior composites of *Social Reticence*, *Disruptive Behavior*, and *Social Competence*. Table 1 gives a detailed breakdown of the measures included in each of these composites. Of the possible 291 participants recruited at 4 months, 212 (73%) had complete data at 9 months, 224 (77%) had complete data at 24 months, 218 (75%) had complete data at 36 months. Reasons for missing data included technical difficulties with the video collection, difficulty scheduling laboratory visit at these ages, family relocating, and permanent attrition (n = 13). Families missing data at 9, 24, and/or 36 months were not significantly different from the overall sample by 4-month temperament group, χ^2 (2, N = 291) = 2.44, p = .30, gender, χ^2 (1, N = 291) = .73, p = .39, or any of the 5-year outcome measures (all p's > .30). Additional data was lost for the 36-month frontal EEG Asymmetry acquisition due to technical difficulties or child refusal. Participants missing EEG data were not significantly different from those with complete data by gender, χ^2 (1, N = 291) = .06, p = .81, but there was a significant difference by 4-month temperament group, χ^2 (1, N = 291) = 6.05, p = .05. Further investigation revealed that there were significantly more control participants missing EEG data at 36 months than participants selected for positive or negative reactivity ($p < .05$).

Of the originally selected 291 participants, 226 had complete maternal report data and 206 had complete peer dyad data at 5 years. Reasons for missing data included technical difficulties with the video collection, difficulty scheduling a laboratory visit, family relocating, and permanent attrition since infancy (n = 13). Participants with missing 5-year maternal report data were not significantly different from those with complete data by gender, χ^2 (1, N = 291) = .57, p = .45 or 4-month temperament group, χ^2 (1, N = 291) = 3.46, p = .18. Participants with missing 5-year peer dyad data were not significantly different from those with complete data by gender, χ^2 (1, N = 291) = 1.62, p = .20, but there was a significant difference by 4-month temperament group, χ^2 (1, N = 291) = 6.72, p = .04. Further investigation revealed that there were significantly more control participants missing peer dyad data at 5 years than participants selected for positive or negative reactivity ($p < .05$).

As described below, the longitudinal analysis of the exuberance measures used maximum likelihood estimation, which allows for missing data longitudinally and assumes the missing data across repeated measures are missing at random (Little & Rubin, 1987; Muthén & Muthén, 2007). An analysis of the exuberance data across infancy and childhood suggests that patterns of missing data did not violate the assumption that it was missing completely at random (MCAR), Little's MCAR χ^2 (9) = 4.91, p = .84. In addition, analyses of the data included in each of the regression analyses discussed below (Exuberance profiles, EEG asymmetry, and 5-year data) suggest that patterns of missing data per analysis do not violate the assumptions of missing data, χ^2 (7) = 5.67, p = .58 and χ^2 (7) = 12.63, p = .08, for 5-year maternal report outcomes and peer dyad outcomes, respectively. Therefore, all available data are used throughout each analysis.

Results

Preliminary Analyses

All measures were examined for assumptions of normality (descriptive statistics reported throughout the methods section above). A series of *t*-tests were used to examine gender effects on all measures. Gender was not associated with any of the measures of positive reactivity, approach, exuberance, or asymmetry across infancy and toddlerhood, all *p*s > .05. However, gender was associated with a number of 5-year outcome measures. Specifically, males were rated as higher on *Externalizing* problems, t (223) = 2.67, p = .01, d = .35, *Surgency*, t (227) = 3.18, p = .00, d = .42, and lower on *Regulation*, t (227) = −2.85, p = .01, d = .38, than females. In addition, males displayed greater *Social Competence*, t (204) = 2.03, p = .04, d = .29, and greater *Disruptive Behavior*, t (204) = 2.40, p =.02, d = .33, than females during the peer dyad assessment. Given these effects, gender was entered as a control variable in all predictive analyses including 5-year *Externalizing* behavior, *Surgency*, *Regulation*, *Social Competence*, and *Disruptive Behavior* as dependent variables.

Analysis of Variance (ANOVA) was used to examine 4-month temperament group differences on all independent and dependent measures at 9 months, 24 months, 36 months, and 5 years of age. Temperament group at 4 months was significantly related to 9-month *Positive Approach*, F (2, 211) = 3.20, p = .04, η_p^2 = .03, with the 4-month positive reactivity, M = .02, SD = .45, and the control group, M = .04, SD = .53, displaying significantly greater 9-month positive approach than the negative reactivity group, M = -.14, SD = .46. Temperament group was not significantly associated with any of the 24 month and 36 month exuberance, or the 5-year outcome measures, all *p*s > .05.

Pearson correlations were used to examine relations between all continuous independent and dependent measures at 9, 24, 36 months, and 5 years of age. In addition, all correlations were confirmed via visual inspection of scatter plots. *Positive Approach* at 9 months was significantly related to 24-month *Exuberance*, r (166) = .22, p = .01, d = .45. In addition, *Exuberance* at 24 months was significantly related to 36-month *Exuberance*, r (193) = .31, $p < .001$, d = .65, and 5-year *Social Reticence*, r (180) = −.24, p = .001, d = .49. Finally, *Exuberance* at 36 months was significantly related to 5-year *Surgency*, r (195) = .29, $p < .001$, d = .60, and 5-year *Social Reticence*, r (183) = −.16, p = .03, d = .32.

Longitudinal Profiles of Exuberance

In order to examine associations between longitudinal patterns of exuberance and outcomes at 5 years, latent longitudinal profiles of exuberance were estimated. To generate these profiles, latent class analysis (LCA), a subtype of Structural Equation Mixture Modeling (SEMM), was performed using Mplus 5.21 (Muthén & Muthén, 2007). This type of analysis seeks to identify unmeasured (i.e., latent) class membership among participants using both categorical and/or continuous observed indicator variables, as in structural equation modeling. Although similar to cluster analysis, LCA offers many advantages over traditional cluster techniques. First, use of SEMM's maximum likelihood (ML) method assumes the data are missing at random, which allows the model parameters to be informed by all cases that contribute a portion of the data, and is recommended as an appropriate way to accommodate missing data ((Little & Rubin, 1987; Schafer & Graham, 2002). An analysis of the exuberance data across infancy and childhood suggests that patterns of missing data did not violate the assumption that it was missing completely at random (MCAR), Little's MCAR χ^2 (9) = 4.91, p = .84, φ = .13. Second, unlike traditional cluster analysis algorithms, which group cases near each other by some definition of distance (e.g., Euclidean distance for k-means cluster analysis), the LCA approach relies on a formal statistical model based on probabilities to classify cases. The ML method estimation iteratively calculates model parameters to be those which are most likely to account for observed results. Then classification is based on Bayes' theorem, which computes a posterior probability (based on a function of the model's parameters) of membership for each latent class. Individuals are then assigned into a latent class for which their posterior probability is highest (Dayton, 1998, McCutcheon, 1987, Muthén, 2004).

In the present study, longitudinal latent classes were estimated using the observed measures of exuberance at 4, 9, 24, and 36 months of age. Specifically, a categorical indicator of positive reactivity group membership at 4 months (0 = not in positive group, 1 = in positive group), the *Positive Approach* composite at 9 months, and the *Exuberance* score composites at 24 and 36 months were used to define the longitudinal profiles of exuberance in the current sample. A model using the individual scores of positive affect, approach, and sociability at 24 and 36 months resulted in the same profiles, thus the more simplified version (i.e., using composites of exuberance) is presented here. Since different measures were used across time, the average proportion of 4-month positive group membership, as well as the average level of 9-month *Positive Approach*, 24- and 36-month *Exuberance*, were estimated independently within each class (i.e., latent profile analysis (LPA; Gibson, 1959), as opposed to estimating latent growth parameters (i.e., intercept and slope). Models with 1 through 4 profiles were tested. Best model fit was assessed using Bayesian information Criteria (BIC), where the lowest number indicates best fit. This index has been shown to identify the appropriate number of groups in finite mixture models and penalizes the model for the number of parameters, thus guarding against models overfitting the data. In addition, the Lo-Mendell-Rubin Likelihood ratio test (LMRL) was also used, which tests the significance of the −2 Loglikelihood difference between models with k and k−1 profiles (Lo, Mendell, & Rubin, 2001).

The LPA was computed using all 291 participants who had data at least for one time point (i.e., 4-months of age). Model fit (BIC) for the current sample was 889.05 for one profile, 884.21 for two profiles, 906.17 for three profiles, and 928.52 for four profiles. The LMRL showed that the 2-profile model was significantly better than the 1-profile model ($p < .01$), however, the 3-profile model was not significantly better than the 2-profile model ($p = .40$), and the 4-profile model was not significantly better than the 3-profile model ($p =.30$). In addition, the 4-profile model produced reliability problems with the estimates. Given the lowest BIC value was combined with a significant LMRL for the 2-class model, this model was chosen as the best-fitting model. The posterior probabilities of membership were high ($M = .83$), reflecting adequate confidence in profile assignment. The "high exuberance" profile ($n = 83$; 28%; 50 females) displayed a higher percentage of membership in the 4-month positive group (46%), and higher levels of 9-month positive approach, 24-month exuberance, and 36-month exuberance. The “low exuberance” profile (*n* = 208; 72%; 105 females) displayed a lower percentage of membership in the 4-month positive group (31%), and lower levels of 9-month positive approach, 24-month exuberance, and 36-month exuberance. Means of each standardized exuberance measure from 9 to 36 months are presented in Figure 1 for each latent class. This figure shows that the two classes were indeed very distinct and their distribution of scores was non-overlapping at each measurement point. However, for the remaining analyses, the continuous probability score of membership in the “High Exuberance” profile was used as the measure of *Exuberance profile* in order to preserve the level of individual variability.

Profiles of Exuberance and 5-year Outcomes

A series of hierarchical linear regressions were computed to test the associations of the longitudinal profiles of exuberance, EEG asymmetry, and their interaction with measures of behavior and temperament outcomes at 5 years of age. When appropriate, gender was controlled for in the first step and the interactions were entered on the second step of each regression analysis. Both the “high exuberance” probability score and the frontal EEG asymmetry score were mean-centered and multiplied together to compute the interaction term. These mean-centered scores and interaction terms were used in the regression analyses (See Tables 2 and 3). Interactions were then probed and plotted according to standards outlined by Aiken and West (1991). High (left) and low (right) values of the moderator (frontal EEG *Asymmetry*) were computed as +/− 1 *SD* (.13) when investigating any significant interactions. Follow up statistical tests from these probes are noted in the text below.

Predicting 5-year maternal report measures

Individual regressions were computed for the maternal report measures of *Internalizing*, *Externalizing*, *Surgency*, *Reactivity*, and *Regulation* composites from the 5-year assessment (See Table 2). There were no main or interaction effects of *Exuberance profile* or *Asymmetry* on 5-year Internalizing, Reactivity, or Regulation. However, *Exuberance profile* and *Asymmetry* did significantly interact to predict ratings of 5-year *Surgency*. In addition, their interaction was associated with ratings of 5-year *Externalizing* at a trend-level.

Follow-up regressions revealed that *Surgency* maternal ratings at 5 years were associated with being in the high *Exuberance profile*, but only when children exhibited left frontal EEG *Asymmetry* (Figure 2). Specifically, when children exhibited left frontal EEG *Asymmetry*, the probability of being in the high *Exuberance profile* was positively related to higher ratings of *Surgency* at 5 years, B = .61, SE(B) = .26, $CI(B)_{.95}$ = .09 – 1.13, β = .28, *t* (129) = 2.32, *p* = .02. However, when children exhibited right frontal EEG Asymmetry, the probability of being in the high Exuberance profile was not significantly related to *Surgency*, B = −.15, SE(B) = .27, $CI(B)_{.95}$ = −.68 – .39, β = −.07, *t* (129) = −.56, *p* = .58.

Follow-up regressions revealed that *Externalizing* problems at 5 years were associated with being in the high *Exuberance profile*, but only when children exhibited left frontal EEG Asymmetry (Figure 3). While this was only a trend-level interaction effect, the simple slopes analyses showed that there was indeed a close to significant effect for the probability of being in a high *Exuberance profile* on *Externalizing* problems when children exhibited left frontal EEG *Asymmetry*, B = 4.61, SE(B) = 2.29, $CI(B)_{.95}$ =.08 – 9.14, β = .25, *t* (128) = 2.01, *p* = .05. However, when children exhibited right frontal EEG *Asymmetry*, the probability of being in a high *Exuberance profile* was not significantly related to *Externalizing* problems, B = −1.66, SE(B) = 2.37, $CI(B)_{.95}$ =−6.36 – 3.03, β = −.09, *t* (129) = −.70, *p* = .49.

Predicting 5-year peer dyad behavior measures

Individual regressions were computed for the observed measures of *Social Reticence*, *Disruptive Behavior*, and *Social Competence* from the 5-year peer dyad assessment (See Table 3). There was a main effect of *Exuberance profile* on 5-year *Social Reticence*, such that the greater the probability of having a high *Exuberance profile*, the lower the frequency of Social Reticence behavior during the 5-year peer dyad assessment. There was also a main effect of 36-month frontal EEG *Asymmetry* on 5-year *Disruptive Behavior*, so that children with greater left frontal *Asymmetry* scores at 36 months displayed greater *Disruptive Behavior* during the 5-year peer dyad assessment. There was also a significant interaction of *Exuberance profile* and *Asymmetry* on 5-year Social Competence.

Follow-up regressions revealed that *Social Competence at* 5 years was associated with being in the high *Exuberance profile*, but only when children exhibited left frontal EEG *Asymmetry* (Figure 4). Specifically, when children exhibited left frontal EEG *Asymmetry*, the probability of being in a high *Exuberance profile* was positively related to greater *Social Competence* behaviors at 5 years, B = .49, SE(B) = .22, $CI(B)_{.95}$ = .06 – .92, β = .29, *t* (122) = 2.26, *p* = .03. However, when children exhibited right frontal EEG *Asymmetry*, the probability of being in a high *Exuberance profile* was not significantly related to *Social Competence*, B = −.15, SE(B) = .22, $CI(B)_{.95}$ = −.59 – .29, β = −.09, *t* (122) = −.68, *p* = .50.

Discussion

The current study examined multiple indicators of exuberance across infancy and toddlerhood to investigate their longitudinal stability, as well as the adaptive and maladaptive outcomes of this temperamental profile at 5 years of age. From a motivational systems perspective, exuberance is likely supported by an underlying motivation to approach (Fox, 1991; Gray, 1982). Continuity in these approach biases have been suggested to result in multifinality, whereby different outcomes may result due to additional intervening factors (Polak-Toste & Gunnar, 2006). Furthermore, previous literature has found exuberance to be associated with both externalizing behavior problems and prosocial behavior (Rydell et al., 2007; Stifter et al., 2008). However, few developmental studies have examined exuberance over time or mitigating factors in its relation to social-emotional outcomes.

Overall, the current results suggest moderate levels of stability and continuity in exuberance, across infancy and toddlerhood. Results revealed that infants selected at 4 months for high levels of positive reactivity to novelty were more likely to show greater positive approach to both joy- and fear-eliciting stimuli at 9 months of age. In addition, levels of infant positive approach at 9 months were associated with greater overall exuberance at 24 months, which included positivity, approach behavior, and sociability with an experimenter. Finally, levels of overall exuberance at 24 and 36 months of age were found to be relatively stable across toddlerhood. Within the developmental literature, positive reactivity, approach behavior, and sociability, all have been associated with the construct of exuberance (Putnam & Stifter, 2005; Pfeifer et al., 2002; Rothbart et al., 2001), and are believed to be supported by similar neural systems linked to the behavioral activation and facilitation systems (Depue & Collins, 1999; Gray & McNaughton, 2000).

When examining a latent profile analysis of each of these indices of exuberance, measured across infancy and toddlerhood, two longitudinal patterns of exuberance were found: a stable, high pattern and a low pattern. In addition, as expected, every one of the exuberance factors examined (i.e., positivity, approach, and sociability) differentiated these longitudinal patterns, suggesting that at high levels, all are indicators of exuberance (Figure 1). While few studies have examined the longitudinal stability and continuity of multiple exuberance factors, these results confirm the high level of stability suggested by previous studies (Fox et al., 2001; Putnam & Stifter, 2005). In addition, these profiles support the idea that low exuberance may not equate to extremely inhibited tendencies. Whereas, the low exuberance profile was statistically lower on all measures of exuberance, the low profile's means were quite similar to the overall sample means. On the other end of the continuum, high exuberance is not necessarily just low behavioral inhibition. While far from conclusive, these findings support the notion that exuberance and behavioral inhibition are related, but separable dimensions of temperament. The current findings suggest that a subset of children exhibit consistently high levels of exuberant behavior and affect, which includes positivity, approach behavior, and sociability, throughout infancy and toddlerhood. Future work should examine the exact interplay between these longitudinal patterns of exuberance and longitudinal patterns of behavioral inhibition. Also, it is important to note that additional longitudinal patterns may exist in an unselected community sample, or within a particular assessment point. Further research should replicate and confirm these patterns in different samples before they are considered representative of the population (Bauer & Curran, 2004).

In addition to investigating the stability and continuity of exuberance over time, the present study examined whether these longitudinal patterns were related to social-emotional outcomes at 5 years of age. Furthermore, patterns of resting frontal EEG asymmetry were thought to moderate these longitudinal associations. Given that exuberance is suggested to reflect a strong motivation to approach, supported by biological approach and reward related systems, there are multiple behavioral profiles that might result from this style of temperament (Polak-Toste & Gunnar, 2006; Stifter et al., 2008). While the heightened positive affect and approach of social novelty would likely lead to greater sociability, links with greater reward expectancies might result in frustration and aggression when these rewards or goals are blocked (Depue & Collins, 1999). Patterns of left frontal EEG asymmetry are thought to indicate a general motivation to approach and have been associated with positive affect, while patterns of right frontal EEG asymmetry are thought to indicate a motivation to withdraw and have been associated with negative affect (Davidson, 1994; Davidson & Fox, 1989). Therefore, children who display a heightened, stable level of exuberance and left frontal EEG asymmetry would be considered to have consistent positive, approach tendencies, whereby they would be more likely to evidence even greater approach behaviors in early childhood, as opposed to those with just heightened exuberance or just left frontal EEG asymmetry. However, the literature is not clear as to whether left frontal EEG asymmetry would enhance relations toward adaptive, sociable behavior or maladaptive, disruptive behavior. Given the associations between left frontal asymmetry and positive affect, it is possible that the combination of exuberance and this electrophysiological profile would lead to greater social competence and sociability. However, as anger and aggression have also been linked to approach behaviors and physiological approach motivation (Harmon-Jones & Allen, 1998; He, Degnan, McDermott, Henderson, Hane, & Fox, 2010), it is possible a pattern of left EEG asymmetry would also enhance disruptive behavior problems. In the current study, frontal EEG asymmetry was examined in toddlerhood as a proximal indicator of the motivational tendency to approach or withdraw. Overall, the current study explored whether exuberance related to both adaptive (i.e., social competence) and maladaptive (i.e., disruptive behavior) outcomes. In addition, frontal EEG asymmetry was examined as a potential moderator of these associations.

In terms of social behavior at 5 years of age, children with a greater likelihood of following a high, stable exuberance profile were found to display less Social Reticence with an unfamiliar peer two years later. Frontal EEG asymmetry did not moderate this association. This result supports previous work connecting exuberance to low levels of shyness (Fox et al., 2001; Rothbart et al., 1994). However, the current results also extend this literature by demonstrating an association between high, *stable* patterns of exuberance across early childhood and observed social withdrawal behavior. Given that exuberant, approach-driven children would likely have low levels of behavioral inhibition, this result is somewhat expected. Previous research suggests that early behavioral inhibition transitions into social reticence as development progresses (Rubin, Coplan, & Bowker, 2009), thus, the current measure of social reticence is thought to reflect behaviorally inhibited behavior at 5 years of age. While the current association may call into question the independence of temperamental inhibition and exuberance, it is important to note that a post-hoc analysis of the Social Reticence means by exuberance profile revealed that the average reticence score for the low exuberance profile was almost identical to the average reticence score for the entire sample. So, while high exuberance children would be expected to display little social wariness with an unfamiliar peer, low exuberance children are not necessarily more likely to display greater social wariness. These mean differences support the idea that temperamental inhibition and exuberance are related, but separable constructs. Similar findings were reported by Pfeifer and colleagues (2002), who found high exuberance was predicted by average levels, as opposed to low levels, of behavioral inhibition.

Social Competence was also associated with early exuberance; however, this association was moderated by frontal EEG asymmetry. Specifically, children who were more likely to display high, stable exuberance across infancy and toddlerhood and exhibited left, but not right, frontal EEG asymmetry, were reported as having greater Social Competence with an unfamiliar peer two years later (Figure 4). Therefore, children who exhibited an approach-driven temperamental style that was supported by a physiological motivation to approach, displayed greater social competence. For the current study, social competent behavior included positive, sociable behavior that supported the goal of the individual tasks, such as social interest during freeplay or positive affect during freeplay and special toy. Given the theoretical link between exuberance and approach behavior (Polak-Toste & Gunnar, 2006; Putnam & Stifter, 2005), it was expected that children with both heightened behavioral exuberance and left frontal asymmetry would display increased social interest and positive affect while interacting with an unfamiliar peer. In addition, previous work suggests that exuberant temperament is linked to later sociability, positive affect, and social competence (Davey et al., 2003; Fox et al., 2001; Hane et al., 2008; Rydell et al., 2007). For exuberant children, social interaction is likely to be a great reward mechanism, especially in novel situations or contexts. Therefore, it follows that heightened levels of exuberance combined with a physiological motivation to approach would lead to greater positive, sociable behavior.

The current study also found that greater exuberance in toddlerhood was associated with mother-reported surgency and externalizing behavior problems, at 5 years of age, but only when children displayed a pattern of left frontal EEG asymmetry. Specifically, children who were more likely to display high, stable exuberance across infancy and toddlerhood and exhibited left, but not right, frontal EEG asymmetry, were reported as having greater surgency and greater externalizing behavior problems two years later (Figures 2 & 3). Therefore, children who exhibited an approach-driven temperamental style, supported by a physiological motivation to approach, were at greater risk for disruptive behavior. Indeed, while surgency is not consistently considered disruptive, the current measure does include an impulsivity subscale (Rothbart et al., 2001), which links it conceptually to externalizing types of behavior. In addition, these results support the idea of Depue & Collins (1999) that children with a heightened motivation to approach reward would also display greater frustration or anger when their goals were blocked. Additionally, research has shown anger to be associated with approach behavior, but only when supported by left frontal EEG asymmetry (He et al., 2010). Overall, heightened exuberance in early childhood combined with a physiological profile consistent with an approach motivational style seems to also result in greater disruptive types of behavior and personality.

In sum, EEG asymmetry at 36 months influenced the relations between a high, stable exuberance profile into late toddlerhood and 5-year social-emotional outcomes. In general, these results support the motivation-direction perspective for frontal EEG asymmetry, where left asymmetry is associated with approach motivation and right asymmetry is associated with withdrawal motivation (Carver & Harmon-Jones, 2009; Davidson, 1994; Van Honk & Schutter, 2006). An inherent part of this hypothesis is that activation of the approach system supports movement towards desired outcomes or goals. However, it is remarkable that these exuberance-by-asymmetry effects were found in relation to adaptive (i.e., social competence), as well as maladaptive (i.e., externalizing problems), outcomes. Indeed, studies have shown that left frontal EEG asymmetry is associated with positive affect and behavioral approach toward enticing stimuli (Hane et al., 2008; Harmon-Jones, 2004). In addition, however, there is work that suggests that anger, although a negative emotion, is related to the approach system in terms of goal persistence and left resting frontal EEG asymmetry (Harmon-Jones & Allen, 1998; He et al., 2010). In fact, a recent study found that observed infant anger was associated with early approach behavior to novel stimuli, but only when infants had left resting frontal EEG asymmetry (He et al., 2010). The current results extend this literature by revealing that, similar to inhibited profiles (Fox et al., 2001), continuity in approach-related tendencies is influenced by resting frontal EEG asymmetry; with a persisting approach-driven style evident only for those children who show a corresponding profile of high exuberance and left frontal EEG asymmetry. However, unlike profiles of inhibition over time, where right frontal asymmetry mitigates paths to various forms of social withdrawal and anxiety, (e.g., Fox et al., 2001), left frontal asymmetry seems to enhance relations to both adaptive and maladaptive outcomes for children with an exuberant temperament. Indeed, this same type of effect was found in a study examining children of mothers with depression, where left frontal asymmetry was associated with both anxious and aggressive behavior problems (Forbes, Shaw, Fox, Cohn, Silk, & Kovacs, 2006).

While this lack of differentiated effects may be somewhat supported by approach-driven motivational systems, additional factors might account for both the associations with adaptive and maladaptive outcomes and the somewhat weak effect sizes found for the exuberance-asymmetry interactions in the current analysis. Given that, from a motivational framework (Gray, 1982), exuberance is linked closely to approach behavior, outcomes of this temperamental style would be expected to relate to movement towards desired outcomes or goals, such as social interaction with others. However, following Depue and Collins' (1999) framework of the behavioral facilitation system, this strong motivation to approach reward-based stimuli would result in heightened frustration or anger when one's path to these goals was blocked. Therefore, given the context, exuberant children with left frontal EEG asymmetry would be expected to display either positive sociability or disruptive behavior problems. It is important to note that the current results revealed that these children were observed displaying greater social competence, but mothers reported them as greater in externalizing problems. It is conceivable that parents would be in a position to observe many more frustrating situations for an exuberant child, such as asking them to stop playing, wait for dessert, or take turns on the playground. Therefore, while exuberant children in the current study were not observed to display greater disruptive behavior, they might be more prone to that type of behavior in other contexts (i.e., at home or school). Furthermore, additional factors, such as the development of inhibitory control and other regulatory mechanisms would influence levels of both social competence and disruptive behavior, in opposite ways. Perhaps children from this sample have individually varying levels of regulation. If exuberant children developed a greater capacity to regulate their approach tendencies and frustration to goal blockage, they would display less disruptive behavior and greater social competence. In turn, children who did not develop these regulatory skills would display greater disruptive behavior and less socially competent behavior. It is possible that both types of children can be found in the current sample, which would account for the associations with adaptive and maladaptive outcomes, as well as the somewhat modest effects found for the exuberance-asymmetry interactions. Further research is needed to clarify the roles of context and regulation in these differential profiles for exuberant children.

Also of note is the small number of gender effects found. Males were reported to have greater surgency and less regulation, but also were observed to display greater social competence with a peer. However, there were no gender effects on the temperament or EEG asymmetry outcome associations The role of gender and gender socialization may have a particular impact on the development of exuberance over time. Future research should explore how gender influences the development of and perception by others (e.g., parents and teachers) of children's positive affect, approach behavior, and sociability, which were included under the rubric of exuberance in the current study.

Implications & Limitations

A limitation of the current study is that the amount of missing data may have biased the current results by limiting generalizability. Missing data analyses revealed that data was lost primarily from the 4-month control group, which would presumably have less of an impact on the results as loss from either of the extreme temperament groups. In addition, only a small number of participants were lost due to permanent attrition. However, any attrition or missing data can decrease the generalizability of results from the current study to non-selected or more complete samples. In addition, the current level of attrition, combined with the potentially lower power to detect interaction effects (see McClelland & Judd, 1993), may have limited the power to detect more significant effects of exuberance and EEG asymmetry on 5-year outcomes.

A strength of the current study is the longitudinal LPA approach used to form the profiles of exuberance. These profiles were formed on the basis of probabilities, which allows for the possibility that there is uncertainty in which profiles people belong to and allows one to predict outcomes using the probability of membership in a group. LPA also offers the flexibility to describe behavior over time when the measurement of behavior changes, which is against the assumption of most variable-based or growth modeling approaches. Overall, the current approach is a useful tool for describing individual differences; however, it is important not to reify the latent profiles, as they do not necessarily represent qualitatively distinct groups in the population and may not be generalized to other samples. In particular, the structure and number of exuberance profiles over time may be different in the overall population. Thus, the current analysis should be replicated in other samples in order to validate both the formation of the latent profiles and the associations with later outcomes over time.

The current results suggest that positive affect, approach behavior, and sociability, all contribute to one's level of temperamental exuberance. In addition, the existence of a stable, high exuberance profile across infancy and toddlerhood was supported. Finally, exuberance was shown to exhibit multifinality, and converged on a combination of adaptive (i.e., social competence) and maladaptive (i.e., externalizing problems) behaviors. However, many of these results were only found when children's electrophysiology also supported a motivation to approach. In addition, these effects were somewhat modest, as the range of scores in Figures 1–3 suggest. Therefore, additional factors must be implicated in distinguishing these outcomes further, while EEG asymmetry likely is supportive of an already heightened level of approach, but does not seem to guide whether children display adaptive or maladaptive behaviors in early childhood. Additional work should examine multiple subtypes of exuberant and socially withdrawn temperamental styles (e.g., surgent, sociable, reticent, disinterested, etc) to determine the precise relations among social behavior, approach-withdrawal motivation, and frontal EEG asymmetry. In addition, information from multiple contexts (e.g., home, lab, school, etc) about child behavior would assist in the formation of these distinct sub-groups.

Overall, affective, behavioral, and physiological factors were found to support a general approach bias for exuberant temperament, but did not differentiate the types of social-emotional outcomes that develop by 5 years of age. Future research that examines additional factors (e.g., context or regulatory processes) that might mitigate trajectories of exuberance across time should prove most informative, as the findings reported here confirm the stability of an exuberant temperament that is grounded in approach and reward motivation. In addition, the specific constructs of exuberance should be explored to determine if particular aspects of this temperamental style predispose children to display social competence or disruptive behavior. These lines of research have important implications for children’s social-emotional development across a pivotal time in early childhood, as they begin to enter formal schooling (i.e., kindergarten) and engage in peer interactions on a regular basis.

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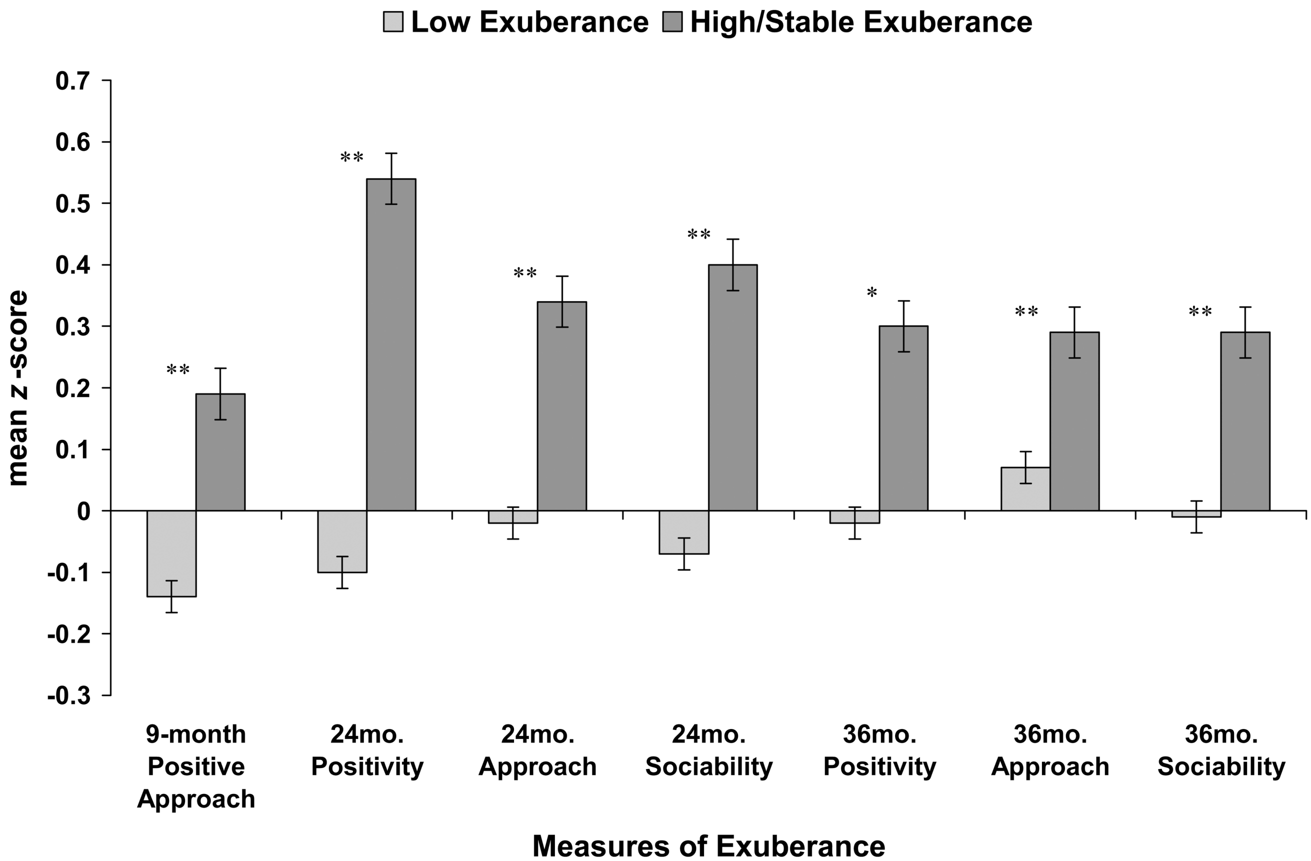

Figure 1.

Latent profiles mean differences on measures of exuberance across infancy and toddlerhood. Note. ** $p < .01$; * $p < .05$

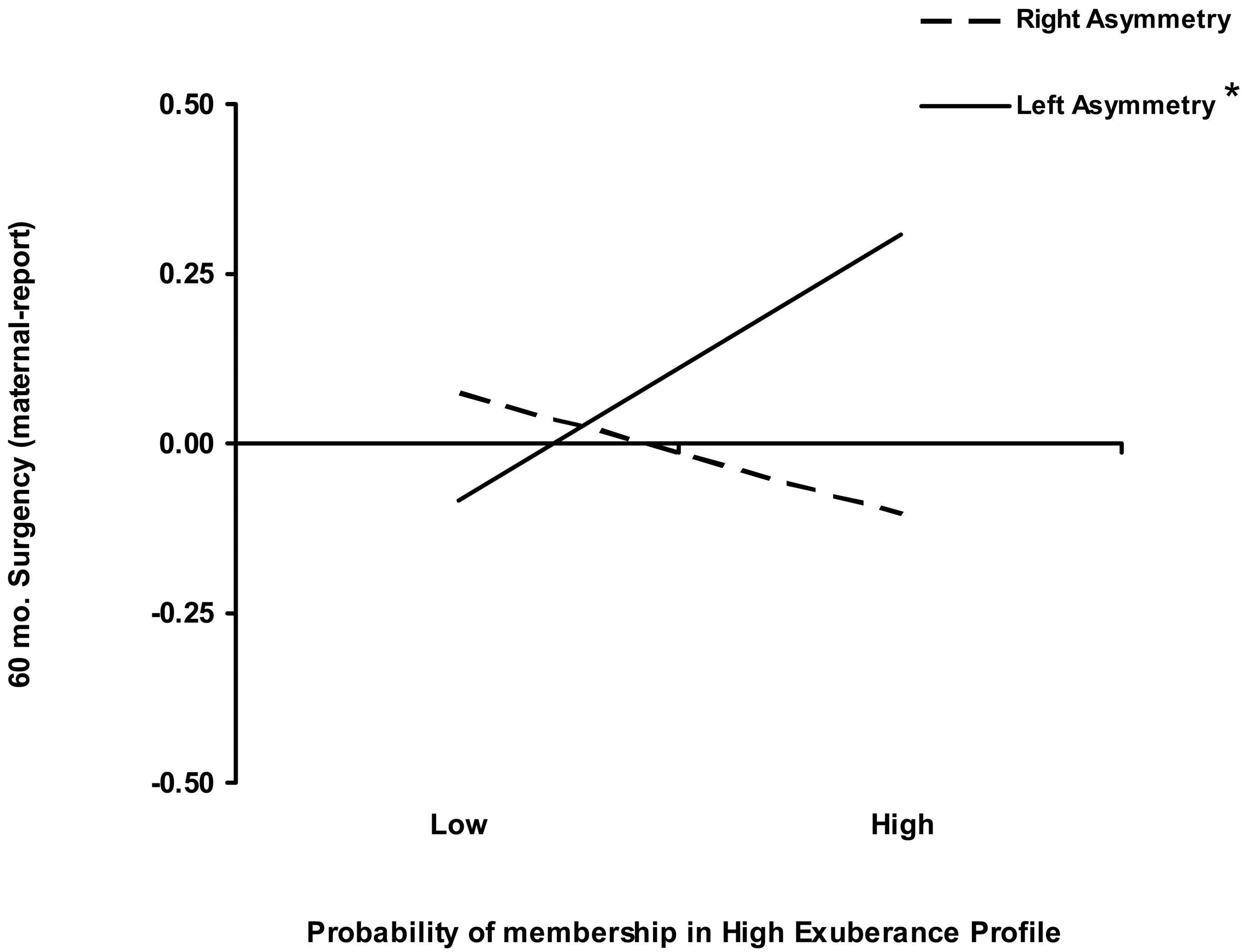

Figure 2.
Probability of high exuberance profile by 36-month frontal EEG asymmetry predicting 5-year Surgency. Note: * $p < .05$

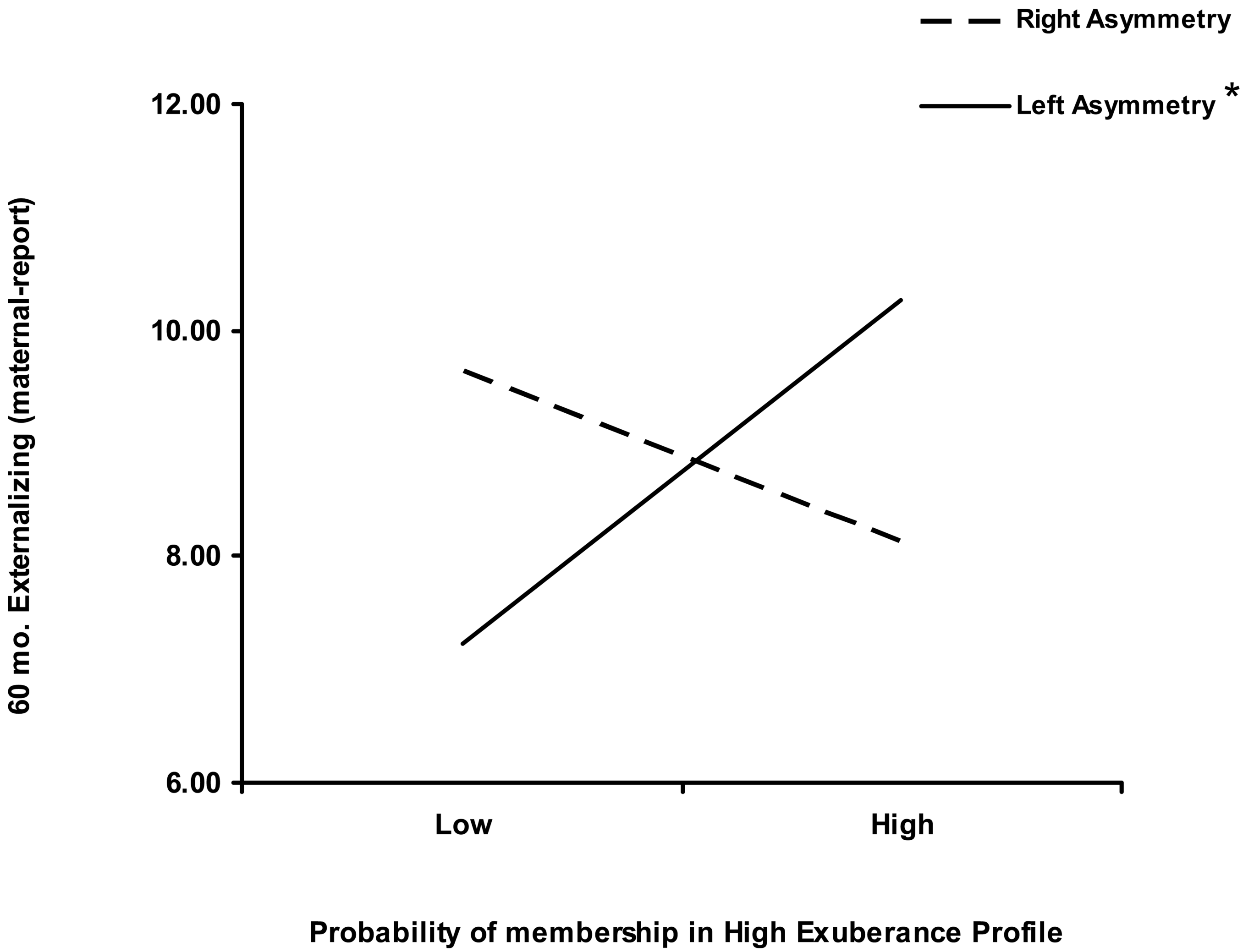

Figure 3.
Probability of high exuberance profile by 36-month frontal EEG asymmetry predicting 5-year Externalizing problem behavior. Note: * $p < .05$

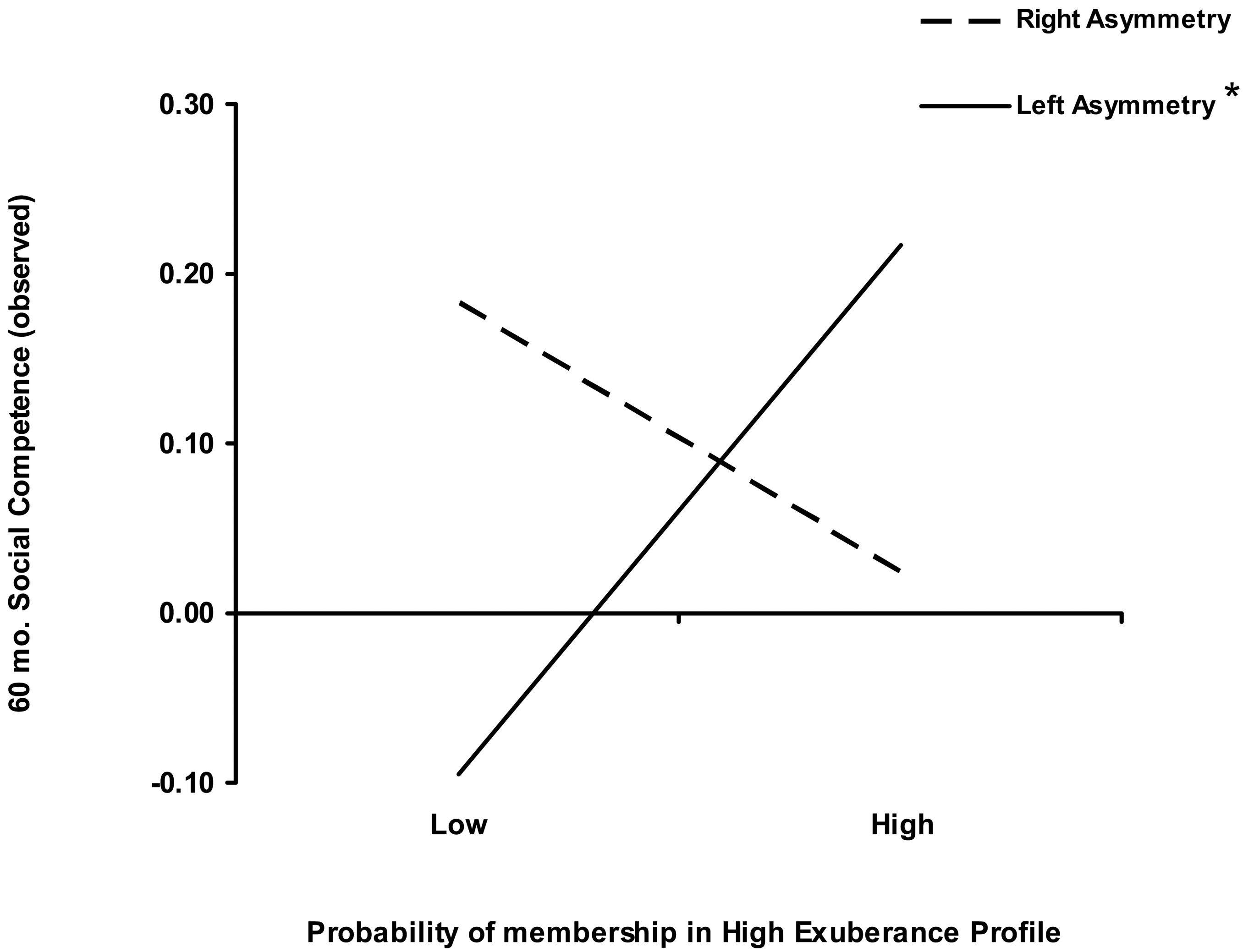

Figure 4.
Probability of high exuberance profile by 36-month frontal EEG asymmetry predicting 5-year Social Competence during a peer dyad. Note: * $p < .05$

Table 1

Study measures by age, construct, and subscales

Age	Construct	Measure	Behaviors/Subscales
4 mo.	Exuberance Profiles	Positive reactivity	positive affect and motor reactivity
9 mo.		Positive Approach	intensity of smiling, positive motor behavior, peak to joy, attention towards puppets, and approach towards stimuli
24 & 36 mo.		Positivity	smiling and positive vocalizations
		Approach	Speed to touch/approach the stimuli, distance from mother, speed to vocalize, activity level, number of prompts (rev.), degree of approach, and willingness to perform each task
		Sociability	proximity, talking, smiling, gesturing, and verbal initiations (all toward experimenter)
36 mo.	Frontal EEG Asymmetry	Baseline EEG	power in right hemisphere minus power in the left hemisphere
60 mo.	Behavior Problems	Internalizing	CBCL emotional reactive, anxious/depressed, somatic complaints, and withdrawn subscales
		Externalizing	CBCL attention problem and aggressive behavior subscales
	Temperament	Surgency	CBQ Surgency, CCTI activity level, CCTI shyness (rev.), and CCTI sociability
		Reactivity	CBQ negative affect and CCTI emotion regulation (reverse-scored)
		Regulation	CBQ effortful control and CCTI attention
	Social Behavior	Social Reticence	FP Social Reticence, CL proportion of time Unoccupied, and ST Passive strategies
		Dysregulation	FP Dysregulated behavior and ST Active strategies, and ST verbal strategies – reverse scored
		Social Competence	FP Social Engagement, ST positive affect, and ST proportion of object acquisition goals

Table 2

Hierarchical linear regression analyses predicting 5-year maternal report outcomes

	Internalizing		Externalizing		Surgency		Reactivity		Regulation	
Variables by step	R^2	β (t)	R^2	β (t)	R^2	β (t)	R^2	β (t)	R^2	β (t)
Step 1 (df 3/129)	.02		.02		.06[t]		.01		.09*	
Gendera				−.12 (−1.37)		−.19 (−2.20)*				.29 (3.33)*
Probability of High Exuberance		−.15 (−1.73)		.09 (.95)		.11 (1.26)		−.07 (−.78)		−.06 (−.71)
Frontal EEG Asymmetry		−.00 (.023)		.03 (.38)		.12 (1.38)		−.01 (−.09)		−.05 (−.60)
Step 2 (df 4/129)	.03		.05[t]		.09*		.02		.10	
Gender[a]				−.11 (−1.19)		−.18 (−2.02)*				.28 (3.20)*
Probability of High Exuberance		−.15 (−1.73)		.08 (.89)		.11 (1.22)		−.07 (−.80)		−.06 (−.68)
Frontal EEG Asymmetry		−.01 (−.10)		−.01 (−.12)		.07 (.82)		−.05 (−.48)		−.02 (−.23)
Probability of High Exuberance × Frontal EEG Asymmetry		.05 (.49)		.17 (1.91)[t]		.18 (2.02)*		.14 (1.51)		−.12 (−1.34)

[t] $p = .06$,

* $p < .05$;

[a] only entered into model when significantly related to outcome measure in preliminary analysis

Table 3

Hierarchical linear regression analyses predicting 5-year peer dyad outcomes

	Social Reticence		Disruptive Behavior		Social Competence	
Variables by step	R^2	β (t)	R^2	β (t)	R^2	β (t)
Step 1 (df 3/129)	.05*		.07*		.06[t]	
Gender[a]				−.13 (−1.48)		−.23 (−2.56)*
Probability of High Exuberance Profile		−.21 (−2.36)*		−.08 (−.85)		.11 (1.16)
Frontal EEG Asymmetry		.04 (.47)		.18 (1.99)*		.03 (.27)
Step 2 (df 4/129)	.05		.07		.09*	
Gender[a]				−.13 (−1.42)		−.22 (−2.46)*
Probability of High Exuberance Profile		−.21 (−2.36)*		−.08 (−.88)		.10 (1.12)
Frontal EEG Asymmetry		.04 (.39)		.15 (1.60)		−.03 (−.36)
Probability of High Exuberance Profile × Frontal EEG Asymmetry		.02 (.17)		.09 (.93)		.19 (1.99)*

[t] $p = .07$,

[*] $p < .05$;

[a] only entered into model when significantly related to outcome measure in preliminary analysis