

Short- and long-term stability of alpha asymmetry in infants: Baseline and affective measures*

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Abstract

Asymmetry in cortical activity was tested for short- and long-term stability during the first year of life. Infants ($N = 129$) completed a total of four laboratory visits: two visits occurred about 1 week apart when infants were 6 months old, and two visits occurred about 1 week apart when infants were 12 months of age. At each laboratory visit, EEG readings were taken during five 1-min, neutral baselines as well as during a negative and a positive emotion-eliciting task. The stability of hemispheric asymmetry was assessed at midfrontal (F3/4, F7/8) and parietal (P3/4) electrode sites. Asymmetry in baseline and fear-eliciting episodes showed moderate short-term stability. Long-term stability was apparent when assessments were composited at 6 months and 12 months. Frontal asymmetry was greater than parietal asymmetry for baseline recordings. There was minimal evidence for stability in asymmetry during positive emotion tasks. Results are discussed with regard to the collection and interpretation of alpha asymmetry measures during infancy.

KEYWORDS

development, EEG asymmetry, emotion, infancy

1 | INTRODUCTION

Asymmetric activity in the brain's frontal hemispheres within the alpha frequency range is generally considered a reliable means of assessing trait-level individual differences in approach-withdrawal tendencies and emotion behaviors from infancy through adulthood (Davidson, 1992, 1994; Davidson & Fox, 1989). In general, greater activity in the right, relative to left, frontal hemisphere (i.e., right frontal asymmetry) during baseline assessments is linked with greater propensities for withdrawal and negativity (Davidson & Irwin, 1999). Conversely, left frontal asymmetry is associated with enhanced propensities for approach and certain types of positive affect (Davidson & Irwin, 1999; Harmon-Jones & Allen, 1998).

Lateralized activity at baseline is apparent in infants within the first 5 days of life (Field, Diego, Hernandez-Reif, Schanberg, & Kuhn, 2002) and appears to be linked to similar approach-withdrawal tendencies in both infants and adults. For example, greater baseline right frontal asymmetry is observed between 3 and 13 months of age in infants of depressed relative to nondepressed mothers; these infants of depressed mothers tend to exhibit high propensities for withdrawal and negative affect (Dawson et al., 1999; Field, Fox, Pickens, & Nawrocki, 1995). Additionally, infants between 10 and 24 months of age who cried during maternal separation showed greater right frontal asymmetry at baseline than did noncriers (Davidson & Fox, 1989; Fox, Bell, & Jones, 1992).

In adults, measures of asymmetry from baseline recordings show high test-retest reliability and internal consistency (Tomarken, Davidson, Wheeler, & Kinney, 1992). High levels of stability in measures of baseline asymmetry are consistent with the interpretation of asymmetry as a marker of

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trait-level propensities that manifest in consistent ways over time. Despite apparent similarities in the implications for baseline asymmetry over time, the stability of asymmetry measures in infants is not well understood. Lower levels of stability may reasonably be expected in infants given the vast changes in both neural structure (Barkovich, Kjos, Jackson, & Norman, 1988) and displays of affective behaviors visible during this period (Goldsmith et al., 1987; Shiner et al., 2012).

To our knowledge, only three studies have investigated the stability in measures of frontal asymmetry over time in young children. High levels of stability in baseline asymmetry were apparent in a special population—children of depressed mothers—from 3 to 6 months of age (Jones, Field, Davalos, & Pickens, 1997). However, as suggested by the authors, the long-term effects of maternal depression on infant development may lead to higher levels of stability in frontal asymmetry for infants of depressed mothers relative to typically developing infants. Separate work by Fox and colleagues (1992) partially addresses this issue. They reported moderate to high levels of stability in asymmetry scores across short (1 month) periods of time for typically developing infants between 7 and 12 months of age. Stability in asymmetry across longer periods (2–3 months) was generally apparent only after 9 months of age. Similarly, Howarth, Fettig, Curby, and Bell (2016) reported moderate stability in asymmetry from 10 to 24 months of age and limited stability between 24 and 36 months. Such findings illustrate the need to systematically compare levels of short- and long-term stability in frontal asymmetry measures across the first year of life. Differences in levels of short- and long-term stability may have implications for planning, executing, and interpreting research that includes assessments of asymmetry in infants. Therefore, examining short- and long-term stability in infant frontal asymmetry during the first year of life was one goal of our study.

No studies have systematically examined stability in measures of frontal asymmetry during nonbaseline episodes. The capability model of frontal EEG asymmetry posits that measures of asymmetry derived from emotion contexts offer unique information about an individual's capacity to employ or inhibit approach or withdrawal behaviors in response to contextual demands (Coan, Allen, & McKnight, 2006). A limited amount of work has attempted to associate infants' affective and approach-withdrawal behaviors with asymmetry in nonbaseline, emotion-eliciting episodes. Increased left frontal asymmetry has been observed in 10- to 12-month-old infants in response to a positive film clip (Davidson & Fox, 1982) and in 10-month-old infants who reached for their mothers during an approach task (Fox & Davidson, 1987). Similarly, increased right frontal asymmetry in 10-month-old infants has been linked to increased fear behavior in multiple

fear during both a social (i.e., interaction with a stranger) and nonsocial (i.e., presentation of a toy spider) fear-eliciting episodes (Diaz & Bell, 2012). However, none of this work provided longitudinal estimates of stability in asymmetry during infancy. The capability model suggests that measures of asymmetry during emotional challenges are highly robust to error and thus more stable than baseline asymmetry (Coan et al., 2006). If this is the case, such measures may be preferable during the infant period, when psychophysiological methods often result in substantial artifact and/or missing data. Alternatively, such measures may be less stable during infancy, as emotions and emotion behaviors undergo vast developmental change (Camras & Fatani, 2008; Sroufe, 1996). Therefore, examining stability in frontal asymmetry during periods of positive and negative emotion elicitation was a second goal of our study.

Like emotion-based assessments of frontal asymmetry, measures of posterior asymmetry provide unique information about individual differences in behavioral propensities. While frontal asymmetry is linked to individual differences in approach/withdrawal and emotional valence, asymmetry in posterior regions has been associated with individual differences in arousal (Heller & Nitsche, 1997). Specifically, right parietal activity is linked with high levels of arousal while left parietal activity is linked to low arousal. Although anterior and posterior activity may be related, they are believed to reflect separate dimensions of processing and predict distinct outcomes. As such, frontal and parietal asymmetry may evidence different levels of stability over time. If parietal asymmetry gauges a more general process relative to frontal asymmetry, it may show less stability over time than frontal measures (Coan et al., 2006). Indeed, results from past research including both frontal and parietal measures suggest less stability in parietal, relative to frontal, asymmetry in both children (Fox et al., 1992; Jones et al., 1997) and adults (Tomarken et al., 1992). However, assessments of stability in parietal measures have focused only on baseline assessments. Thus, our final goal was to examine stability of parietal asymmetry across both baseline and emotion-eliciting contexts.

In sum, we aimed to expand understanding of the stability of frontal and parietal asymmetry measures (a) over short and long periods during early infancy, and (b) in both neutral and emotion-eliciting contexts.

2 | METHOD

2.1 | Procedure

Participants were drawn from a longitudinal twin study of emotional development across infancy (Schmidt et al., 2013). To be included in the analyses, infants were required

to be free of known neurological impairments and have a history of right-handedness in their immediate family. Infants ($N = 129$) visited the laboratory on four occasions between 6 and 12 months of age. When infants were approximately 6 months old, they participated in a series of behavioral episodes while EEG data were collected. They repeated the procedure 1–2 weeks later. This procedure was repeated again when infants reached 12 months of age, with one visit closely following the child reaching 12 months of age and an additional visit occurring 1–2 weeks later. Children's mean ages at each visit were 30.05 ($SD = 4.42$), 30.74 ($SD = 2.45$), 54.70 ($SD = 3.99$), and 56.16 ($SD = 3.12$) weeks.

2.2 | Measures

At each laboratory visit, the child was seated in a high chair and fitted with a Lycra electrode cap (Electro-Cap International, Eaton, OH) according to anatomical landmarks. Electroconductive gel (OmniPrep) and Ag/AgCl electrodes were applied to the following sites per the standard 10/20 system: Fp1, Fp2, F3, F4, F7, F8, T3, T4, T5, T6, C3, C4, P3, P4, O1, O2, Pz, Fz, and Cz. The site for electrode Cz, which served as the reference during recording, was lightly abraded prior to electrode application. All impedances were reduced to less than 20 k Ω prior to recording, and electrodes at homologous sites were kept within 5 k Ω of one another. EEG data were sampled at a rate of 500 Hz and amplified with a gain of 20,000. High-pass and low-pass filters were applied during recording at cutoffs of 1 Hz and 200 Hz, respectively.

Participants then completed a resting baseline assessment followed by three emotion-eliciting episodes. As is typical for studies of individual differences in emotion, all participants completed the episodes in the same order. The first two emotion episodes were designed to elicit fear (first episode) and positive affect (second episode) while physiological data were recorded. A third episode, designed to elicit frustration, did not produce enough artifact-free data to be included in the analyses, as this task elicited high levels of movement in infants. Therefore, the frustration episode is not discussed further.

2.2.1 | Baseline

Infants first completed a series of five 1-min recording periods. For this, infants and their parent received instructions from the experimenter, who then left them alone together in the experimental room. An auditory signal indicated the beginning of each recording period, during which the parent was instructed to refrain from talking but to hold up a series of interesting toys to keep the infant's attention captured.

A second auditory signal indicated the end of each recording period.

2.2.2 | Stranger approach

Following the conclusion of the baseline period, a stranger approach procedure that elicits fear and wariness in young children was employed (Goldsmith & Rothbart, 1999). For this, a male stranger entered the experimental room. The stranger turned to look at the child and then paused for 10 s. After this, the stranger moved approximately half of the distance toward the child, where he paused for 5 s and then said, "Hello (child's name), I'm going to come a little closer to you." The stranger then approached to within 1 foot of the child and stood next to him/her for 2 min. Following this, the stranger turned away from the child and left the room. Parents remained in the experimental room but were asked to refrain from interacting with the child. Recording was discontinued if the child displayed 30 s of intense crying.

2.2.3 | Peek-a-boo

A peek-a-boo task was used to elicit positive affect in infants (Goldsmith & Rothbart, 1999). At the beginning of this task, the primary experimenter reentered the room and instructed the parent and child in a game of peek-a-boo. The task involved the parent moving behind a wooden screen while the experimenter asked, "Where's Mommy?" After a 3-s delay, on the experimenter's cue, the parent emerged from behind the screen, smiling and saying "Peek-a-boo." After 3 s, the next trial began. Parent-infant dyads each completed a series of three trials.

2.2.4 | EEG data scoring

Data were rereferenced offline to a whole-head average reference, with a minimum of 12 sites evenly distributed across the head (Bertrand, Perrin, & Pernier, 1985). All data were visually scored and edited to remove artifacts resulting from eye movements, muscle activity, and/or gross motor movements. A fast Hartley transform (Bracewell, 1984) was applied to artifact-free chunks that were a minimum of 1.024 s in duration. Alpha power was defined as power density in the 5–9 Hz frequency band. This band of frequencies was selected because it includes those frequencies that approximate the adult alpha frequency band (Marshall, Bar-Haim, & Fox, 2002) and in order to maintain consistency with previous published work from this sample (Buss et al., 2003). Alpha power was not calculated for infants who had fewer than 30 s of usable EEG data. Although the 30-s requirement may be longer than needed (Möcks & Gasser, 1984), it is roughly half of that typically used for adults. This

TABLE 1 Short- and long-term stability in frontal asymmetry during baseline

	F3/4		F7/8		P3/4	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
Short-term stability (1–2 weeks)						
6 months	.253	.10	.686**	< .01	.451**	< .01
12 months	.377*	< .04	.426*	< .01	.162	.12
Long-term stability (6 months)						
6 months to 12 months	.319*	.01	.604**	< .01	.174*	.03
Average long-term stability (6 months) when only one occasion at each age is used						
6 months to 12 months	.214		.506		.285	

* $p < .05$. ** $p < .01$.

cutoff was applied given the short duration of the emotion episodes. To account for possible differences in episode length and available data, alpha power was weighted by the proportion of the total number of seconds of artifact-free data available. This procedure is similar to that employed by Tomarken and colleagues (1992). The number of seconds of clean data was unrelated to asymmetry scores at all visits ($|r|s < .28$, $ps > .05$). Asymmetry scores were computed at homologous electrodes by subtracting log-left alpha power from log-right alpha power.

2.2.5 | Missing data

All children in the data set provided usable EEG during a minimum of one of the three previously described episodes. Little's MCAR, $\chi^2(1131) = 972.45$, $p > .10$, suggested that data were missing completely at random. Therefore, we used a full information maximum likelihood (FIML) procedure to account for all missing data. FIML reconstructs the variance-covariance matrix of the requested parameters based on the likelihood of obtaining the observed dataset from the reconstructed matrix. The procedure uses all available data in the estimation algorithm. Maximum likelihood methods are regarded as state-of-the-art procedures for producing unbiased parameter estimates when data are missing at random (Enders, 2010; Schafer & Graham, 2002).

2.3 | Plan for analysis

All analyses were conducted in MPlus version 7, using the `type = complex` command to account for twin relatedness, in three steps. For each episode, we first examined short-term stability in asymmetry. To do this, we calculated the Pearson correlation between asymmetry scores at the two visits at 6 months of age (short-term stability at age 6 months) and 12 months of age (short-term stability at 12 months of age).

Fisher's r to z transform was used to test for significant differences in stability across electrode sites at contemporaneous assessments (Cohen & Cohen, 1983).

Second, we calculated 6-month and 12-month asymmetry composites using the two visits at age 6 months (6-month composite asymmetry) and the two visits at age 12 months (12-month composite asymmetry). These composites were used to test long-term stability by calculating the Pearson correlation between composite asymmetry scores at 6 and 12 months of age. Again, Fisher's r to z transform was used to test for significant differences in stability across electrode sites.

Finally, we recognize that composites that aggregate two assessments may enhance the reliability of measures relative to single assessments. Thus, we also examined long-term stability in asymmetry by calculating the Pearson correlation between asymmetry scores at Visit 1 at age 6 months and Visit 1 at age 12 months and the correlation between Visit 2 at age 6 months and Visit 2 at age 12 months. We report mean correlations to allow for the comparison of measures of long-term stability based on single versus dual assessments.

3 | RESULTS

3.1 | Stability of baseline asymmetry between 6 and 12 months of age

As shown in Table 1, significant short-term stability in baseline asymmetry assessed over a period of 1 week was seen at F7/8 and P3/4 but not at F3/4. Fisher's r to z transform suggested that, at 6 months of age, short-term stability in asymmetry at F7/8 was greater than stability in asymmetry at F3/4 ($z = -3.79$, $p < .01$) and stability in asymmetry at P3/4 ($z = 2.31$, $p = .01$). Short-term stability at P3/4 was marginally greater than stability at F3/4 ($z = -1.48$, $p < .07$). Thus,

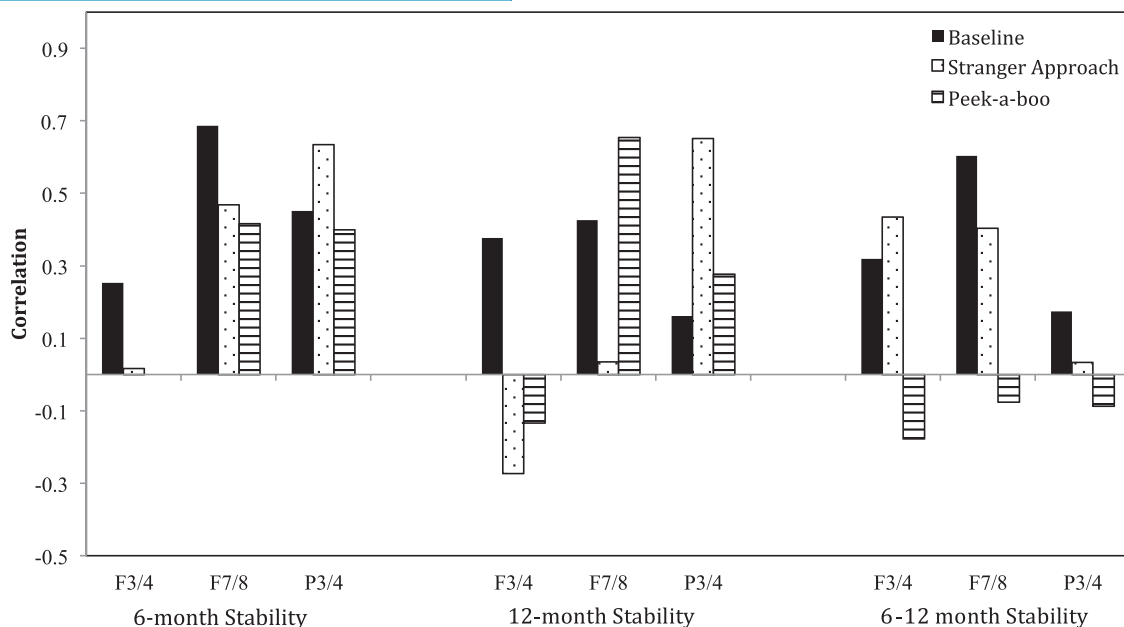


FIGURE 1 Alpha asymmetry stability across contexts

the greatest short-term stability in baseline asymmetry at 6 months of age was observed at F7/8 electrodes and the least short-term stability was observed at F3/4 electrodes.

At 12 months of age (Table 1), short-term stability in baseline asymmetry over a 1-week period was significant only at frontal electrodes. Fisher's r to z transform suggested that stability in baseline asymmetry at F7/8 was not different from stability in asymmetry at F3/4 ($z = -0.37, p = .36$) but was greater than stability in asymmetry at P3/4 ($z = 1.86, p = .03$). Short-term stability in asymmetry at F3/4 was marginally greater than stability at P3/4 ($z = 1.48, p = .07$). Therefore, the greatest short-term stability in baseline asymmetry at age 12 months was observed at F3/4 and F7/8.

We then used the composites from the 6-month and 12-month visits to examine long-term stability in asymmetry over a period of 6 months (Table 1). The composites suggested significant stability at all electrodes. Fisher's r to z test suggested that long-term stability in asymmetry at F7/8 was greater than stability in asymmetry at F3/4 ($z = -2.93, p < .01$) and long-term stability at P3/4 ($z = -4.16, p < .01$). Long-term stability at F3/4 was marginally greater than long-term stability at P3/4 ($z = 1.23, p = .10$). Thus, the greatest long-term stability, as reflected by the composites, was seen at frontal electrodes with maximal long-term stability observed at F7/8 ($r = .60$).

For comparison, we also derived estimates of 6–12 month stability using only one measure per age. These single-occasion stability estimates were not significantly lower than those derived using the composite measure (all z 's $< 1.11, p$'s $> .10$). Comparisons of stability estimates are illustrated in Figure 1.

3.2 | Stability of asymmetry during fear episode between 6 and 12 months of age

As shown in Table 2, significant short-term stability in asymmetry during a fear episode at 6 months of age was seen at F7/8 and P3/4 but not at F3/4. Short-term stability in asymmetry during a fear episode at F7/8 was greater than stability at F3/4 ($z = 2.84, p < .01$), and marginally less than stability at P3/4 ($z = -1.40, p = .08$). Short-term stability at P3/4 was greater than stability at F3/4 ($z = 4.25, p < .01$). Thus, during a fear episode at 6 months of age, the greatest short-term stability in asymmetry was apparent at P3/4 and the least stability was at F3/4.

At 12 months of age, correlations suggested significant short-term stability only at P3/4. Short-term stability in asymmetry in a fear episode was greater at F7/8 than at F3/4 ($z = -1.80, p = .04$). Again, stability in asymmetry at F7/8 was less than stability at P3/4 ($z = 4.23, p < .01$). Stability in asymmetry at F3/4 was significantly less than stability in asymmetry at P3/4 ($z = -3.19, p < .01$). Therefore, at 12 months of age, the greatest short-term stability was observed at P3/4.

We then examined long-term stability in asymmetry during a fear episode assessed over a period of 6 months using the composites formed at each age (Table 2). Composites suggested greater stability at frontal but not parietal electrodes. Consistent with this, Fisher's r to z showed that stability was greater at both F3/4 ($z = 3.19, p < .01$) and F7/8 ($z = 2.92, p < .01$) relative to P3/4. Stability at F3/4 did not differ from stability at F7/8 ($z = 0.28, p = .39$).

For comparison, we also derived estimates of 6- to 12-month stability using only one measure per age. Stability

TABLE 2 Short- and long-term stability in frontal asymmetry during stranger approach

	F3/4		F7/8		P3/4	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
Short-term stability (1–2 weeks)						
6 months	.016	.86	.468**	< .01	.635**	< .01
12 months	–.273	.19	.035	.58	.651**	< .01
Long-term stability using all data (6 months)						
6 months to 12 months	.434*	< .01	.403**	< .01	.034	.83
Average long-term stability (6 months) when only one occasion at each age is used						
6 months to 12 months	.168		.266		.119	

* $p < .05$. ** $p < .01$.

estimates using the composite measures were greater than estimates derived from single assessments at F3/4 ($z = -2.13$, $p = .02$) but were similar at other electrode sites (z s < 1.12 p s > .13).

3.3 | Stability of asymmetry during pleasure episode between 6 and 12 months of age

As suggested by Table 3, the magnitudes of correlations suggested somewhat limited short-term stability in asymmetry during the positive episode across all electrode pairs. At 6 months of age, short-term stability was greater at F7/8 ($z = -2.75$, $p < .01$) and P3/4 ($z = -2.62$, $p < .01$) relative to F3/4. Short-term stability in asymmetry did not differ between F7/8 and P3/4 ($z = 0.13$, $p = .45$).

At 12 months of age, patterns of correlations suggested significant short-term stability in asymmetry during a positive episode at F7/8 and P3/4. Fisher's r to z showed that

short-term stability was significantly lower at F3/4 than at F7/8 ($z = 5.54$, $p < .01$) and P3/4 ($z = -2.53$, $p = .01$). Short-term stability in asymmetry at F7/8 was significantly greater than stability in asymmetry at P3/4 ($z = 3.01$, $p < .01$). Thus, at 12 months of age, short-term stability in asymmetry during a positive episode was greatest at F7/8.

We then examined long-term stability in asymmetry during a positive episode assessed over a period of 6 months using the composites formed at each age (Table 3). None of the estimates of 6-month stability were significant (p s > .28), and none of the estimates differed from one another (z s < 0.80, p s > .21).

Finally, for comparison, we also derived estimates of 6- to 12-month stability using only one measure per age. Stability estimates using the composite measures were marginally greater than estimates derived from single assessments at F7/8 ($z = 1.33$, $p = .09$) but were similar at other electrode sites (z s < 0.40 p s > .34).

TABLE 3 Short- and long-term stability in frontal asymmetry during peek-a-boo

	F3/4		F7/8		P3/4	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
Short-term stability (1–2 weeks)						
6 months	.000	1.00	.416**	< .01	.399	.21
12 months	–.134	.35	.654**	< .01	.277**	.01
Long-term stability (6 months)						
6 months to 12 months	–.178	.28	–.077	.26	–.087	.61
Average long-term stability (6 months) when only one occasion at each age is used						
6 to 12 months	–.230		–.251		–.075	

* $p < .05$.

4 | DISCUSSION

Our results suggested unique patterns of stability in alpha asymmetry for neutral (i.e., baseline) and emotion-eliciting contexts. The stability of resting infant asymmetry at midfrontal sites was comparable to stability estimates previously observed in adults across a 3-week test-retest period (Tomarken et al., 1992) and between infancy and toddlerhood in a sample enriched for chronic maternal depression (Jones et al., 1997). Stability was particularly evident across shorter periods, which spanned a test-retest period of 1 week in this work. However, relatively high levels of stability in asymmetry were also observed at frontal and midfrontal sites across a period of 6 months when asymmetry scores were based on composite estimates. Specifically, when scores of frontal asymmetry from each 6-month visit were composited and correlated with frontal asymmetry composites created from each 12-month visit, we observed moderate-to-high stability in frontal asymmetry across the second half of the first year of life. This moderate-to-high stability likely reflects increased internal consistency of asymmetry estimates as the number of baseline segments are increased, as has been reported in adults (Tomarken et al., 1992). Such an effect had not previously been demonstrated during infancy. This effect was less robust when single assessments were used. Therefore, for researchers who are interested in estimates of infant frontal asymmetry that reflect trait-level stability, rather than state-level measures, including at least two recordings as the time between assessments lengthens may be necessary to observe the trait-level effects.

Stability in asymmetry during baseline recordings was greatest and most consistently observed at midfrontal recording locations. Measures of frontal and parietal asymmetry appear to reflect different individual propensities, particularly with regard to tendencies for emotional experience. As previously noted, frontal asymmetry may be a unique trait-level marker of affective and approach-withdrawal tendencies in infants (Buss et al., 2003; Davidson & Fox, 1989; Hane, Fox, Henderson, & Marshall, 2008). In contrast, parietal asymmetry may reflect more cognitive processing and general emotional arousal, regardless of valence (Heller, Nitschke, & Miller, 1998; Solomon, O'Toole, Hong, & Dennis, 2014). Therefore, to the degree that posterior asymmetry may reflect cognitive or emotional arousal to a task at hand rather than traitlike pattern of individual differences in behavioral propensities, less consistency over time—particularly during baseline tasks—may be expected.

In contrast to measures of baseline asymmetry, we observed less stability in frontal asymmetry measured during emotion-eliciting episodes. Namely, we observed a moderate degree of short-term stability in asymmetry at midfrontal and parietal sites during fear and positive-affect eliciting epi-

sodes. One reason for limited short-term stability may be the vast changes in emotional development that occur from 6 to 12 months of age. For example, differential emotions theory suggests that, across the first year of life, expressions of pleasure move from a precursory form that is dependent primarily on stimulus recognition to a true basic emotional response that includes more complex cognitive processing (Sroufe, 1996). Similarly, both mean levels and individual differences in fearfulness undergo vast developmental change between 3 and 36 months of age (Brooker et al., 2013; Sroufe, 1977). Other theories on the emergence and development of emotions also suggest inconsistent links between observable facial expressions and other components of emotion, such as physiological systems (Camras & Fatani, 2008). Thus, it is sensible that stability in asymmetry as elicited in emotional contexts may show low levels of stability during this period of developmental change in both positive and fear-based emotion systems.

Short-term stability was observed at parietal sites, suggesting that neural patterns of arousal are consistent across closely spaced assessments. These neural patterns of arousal may develop earlier than physiological responses associated with differentiated emotions. Unfortunately, little research has investigated the timing by which emotion systems become stably aligned with physiological profiles such as measures of frontal and parietal asymmetry. This will be an important avenue for future work.

Our results also suggest that long-term stability was evident during a fear-eliciting but not a positive-affect eliciting episode. This was true at frontal and midfrontal electrode sites and was evident when composite scores of asymmetry were used to compare 6- and 12-month assessments. One reason for this difference may lie in differences in the timing of the development of positive affect and fear. Fear—at least of the type elicited by a stranger approach—is thought to emerge around 6 months of age (Waters, Matas, & Sroufe, 1975) and increase through age 36 months (Brooker et al., 2013; Sroufe, 1977). Unfortunately, the timing of developing positive affect in early infancy has received scant research attention, and the direction of developing associations between EEG asymmetry and affect are only beginning to be investigated (Howarth et al., 2016). Moreover, the possibility of vast individual differences in the differentiation of emotions (Barrett, Gross, Conner Christensen, & Benvenuto, 2001) may also lead to inconsistencies in patterns of physiological arousal during different emotion-eliciting episodes. A second possibility is that less stability in asymmetry associated with positive emotions is related to the limited heritability of positive affect during infancy. In infancy, greater genetic influences are observed for aspects of distress and negative emotion relative to positive emotion (Goldsmith, Buss, & Lemery, 1997; Goldsmith, Lemery, Buss, &

Campos, 1999). Positive affect, in contrast, appears to be strongly influenced by the early environment. Importantly, stable influences in infant affective behavior tend to be heritable influences. Thus, in early life, biological signatures may be more readily apparent for fear propensities than for tendencies for positive affect.

Although a replication of our findings is needed, results offer suggestions for the design of future investigations that incorporate longitudinal assessments of asymmetry. First, our results suggest that multiple baseline assessments or longer baseline recordings may lead to more stable estimates of baseline asymmetry in the first year of life. Although this guideline feels intuitive, it has been offered previously in the absence of empirical support, potentially making it easier to dismiss as subjective opinion. Additionally, longer or greater numbers of baselines are difficult to incorporate at very young ages. We note that several helpful suggestions regarding strategies for keeping infants engaged and reducing artifacts during EEG recording exist in the literature (DeBoer, Scott, & Nelson, 2007; Marshall & Fox, 2008; Trainor, 2008). Many of these are particularly beneficial for baseline recordings.

In addition, our work suggests that measures of EEG asymmetry during the first year of life may not be similarly associated with emotional or physiological responses in the same individual over time. In other words, biology-behavior associations are dynamic rather than fixed. Similarly, temperament theorists argue that a certain degree of instability may be expected as systems develop (Goldsmith et al., 1987; Shiner et al., 2012). Thus, future research should exercise caution in assuming that early findings are consistent with what is known about the development of emotional and physiological systems during the period of development under study.

Finally, the results underscore previous assertions that EEG measures in emotional relative to nonemotional episodes or at frontal relative to parietal electrode sites may reflect different psychological phenomena (Brooker, Phelps, Davidson, & Goldsmith, 2016; Coan et al., 2006; Heller et al., 1998). Moreover, neural correlates of emotion may follow distinct trajectories of development. Again, the appropriate cautions should be taken in the interpretation and generalization of findings.

Although our study provides needed empirical evidence for differing stability of asymmetry measures in early life, it is not without limitations. First, although our sample is larger than (Jones et al., 1997; Tomarken et al., 1992) or comparable to (Howarth et al., 2016) samples used in previous investigations of stability in asymmetry, it is still only moderate in size for the questions being addressed. Thus, replication studies will likely lead to more precise estimates of effect sizes for the types of analyses used here. Second, this work

was conducted in a sample of typically developing twins. Although twins are generally representative of nontwin populations recruited in a similar way (Andrew et al., 2001), the degree to which our results may translate to atypical populations is unknown.

In sum, our results show a moderate level of short- and long-term stability in frontal asymmetry from 6 to 12 months of age when EEG was measured during baseline and fear-eliciting conditions. Stability for long-term measures was greatest when multiple baseline assessments were used. In contrast, stability over the 6-month period was not apparent under positive-affect eliciting conditions. This work has clear methodological implications for future longitudinal research including measures of EEG asymmetry in the first year of life.

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