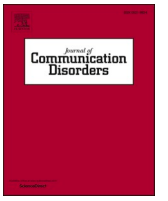
Journal of Communication Disorders 118 (2025) 106564

Contents lists available at ScienceDirect

Journal of Communication Disorders

journal homepage: www.elsevier.com/locate/jcomdis



Infant temperament predicts early communicative skills in the FinnBrain Birth Cohort Study

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ARTICLE INFO

Keywords:
Infant
Toddler
Temperament
Positive emotionality
Self-regulation
Vocabulary
Gesturing

ABSTRACT

Studies have established that dimensions of temperament and language development are associated in childhood. Insofar, however, longitudinal studies from infancy into toddlerhood accounting for all temperament dimensions and covering preverbal communication in addition to emerging verbal skills are scarce. Existing findings are inconclusive.

The current study is an extension of our previous study ($N = 91$) on a large cohort sample ($N = 1200$ and 1039 depending on analysis). Temperament (positive emotionality, negative emotionality and emerging self-regulation) was assessed at 6 and 12 months of age and gesturing and receptive vocabulary at 14 months. As an extension to the previous study, expressive vocabulary and sentence complexity in toddlerhood, at 30 months, were also assessed. All assessments utilized parent reports. Associations were studied by multiple linear regression analysis.

The temperament traits of positive emotionality and self-regulation positively predicted all communicative skills except sentence complexity. Positive emotionality accounted for 10–11 % of the variance in gesturing, 4–5 % in receptive vocabulary and 1–3 % in expressive vocabulary. Self-regulation accounted for 4–6 % of the variance in gesturing, 2–3 % in receptive vocabulary and 0–1 % in expressive vocabulary.

Results aligned with the findings of our prior study but also highlighted weak longitudinal positive associations between positive emotionality and self-regulation and gesturing and vocabulary. However, associations were notably stronger with gesturing compared to verbal skills. Longitudinal weakening of associations suggests the role of infant temperament is replaced by other factors influencing language development moving into toddlerhood.

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https://doi.org/10.1016/j.jcomdis.2025.106564
Received 27 February 2025; Received in revised form 28 August 2025; Accepted 1 September 2025
Available online 4 September 2025

1. Introduction

The importance of adequate communication and language skills in several contexts over the life span, such as academic achievement and behavioral functioning is undebated (Morgan et al., 2015). Consequently, mapping of the factors influencing language and communication development is an important research field. A large proportion of communication and language skills and their precursors are acquired during infancy and toddlerhood. Individual children's communication skills develop at different rates. Growth rates of vocabulary at the earliest ages predict later language skills (Rowe et al., 2012). This indicates that individual differences in communicative skills in the very earliest years of development need to be part of the focus of research seeking protective and risk factors for this development. Given that temperament is one of the innate factors defining infants daily interactions, it naturally possesses a role as a factor needing to be explored in the context of early communicative development. Nevertheless, our knowledge in this field is surprisingly limited.

Temperament is composed of the infant's individual emotional, motor, and attentional reactivity and self-regulation (Rothbart & Bates, 1998). Thereby it contributes to how the infant interacts with both the physical environment and the people present in the infant's life. For instance, temperament is linked to social learning (Rothbart & Bates, 2006). Social interaction is, in turn, the basis of communicative development (Kuhl, 2007). However, the body of literature including measures of infant temperament and communicative skills arching longitudinally into toddlerhood are still relatively scarce, and the samples of such studies are typically modest. Particularly, the knowledge of associations between early temperament and preverbal gesturing is limited, although some evidence of such relations is starting to emerge (Bruce et al., 2022; Ollas et al., 2020; Ollas-Skogster et al., 2023). Gesturing is an important early communication modality and precursor of language development (Iverson & Goldin-Meadow, 2005; Kuhn et al., 2014). The timing of gesturing emerging coincides with temperamental differences becoming more observable and stable. This further motivates studying relations between temperament and gesturing, as it allows observing at what time associations between communicative development and temperament start to emerge.

1.1. Temperament and early communicative development

Temperament is considered to be biologically based, but is modified throughout life due to experience, maturation, and environmental factors (Goldsmith et al., 1987; Rothbart & Bates, 2006). Hence, temperament is relatively stable within an individual, but nonetheless undergoes change, particularly during the earliest years when different skills emerge and develop or are expressed in different ways due to maturation (Caspi & Roberts, 2001; Rothbart & Bates, 2006). Consequently, it is essential to assess associations over different time points since associations may differ depending on point of assessment, especially during the most rapid development of temperament in early life.

Within Rothbart's psychobiological framework, which is applied in the current study, three distinct temperamental dimensions are specified in infancy: positive emotionality, emerging self-regulation, and negative emotionality (Gartstein & Rothbart, 2003). Positive emotionality involves the subscales approach, vocal reactivity, high intensity pleasure, smiling and laughter, activity level and perceptual sensitivity. Negative emotionality is composed of sadness, distress to limitations, fear and falling reactivity. In turn, low intensity pleasure, soothability, cuddliness and duration of orienting form the factor emerging self-regulation (Gartstein & Rothbart, 2003). Some previous work has studied the aforementioned dimensions in relation to infant/toddler language. Typically, positive emotionality is hypothesized to influence communicative development by encouraging social interactions and consequently increasing the amount of communicative experiences and language stimulation (Dixon & Smith, 2000). Empirical results regarding positive emotionality in support of this hypothesis are relatively conclusive: studies report positive relations between the aspects of positive emotionality/extraversion and expressive language (Dixon & Smith, 2000; Kubicek & Emde, 2012; Laake & Bridgett, 2014), including early syntax (Davison et al., 2019), receptive language (Dixon & Smith, 2000; Morales et al., 2000) and early communicative skills (Peterson et al., 2017), also including gesturing (Bruce et al., 2022; Ollas et al., 2020). Some studies have found no significant associations (e.g. Spinelli et al., 2018). Furthermore, in regard to early syntax, the few previous findings have differed somewhat. Davison et al. (2019) report positive associations between the aspects of positive emotionality at 8 months, but not 12 months, and average phrase length at 24 months. Bruce et al. (2022), on the other hand, found no association between 10- and 24-month positive emotionality and syntactic measures at 24 months.

Self-regulation is also hypothesized to have positive associations with communicative development. The suggested mechanism is that self-regulation promotes the communicative development by supporting focusing on interaction and joint attention, leading to the child making better use of the language and communication stimuli in the environment (Dixon & Smith, 2000). The mechanisms behind higher self-regulation supporting communicative development may be related both to the attentiveness and self-regulatory ability that are often involved in measures of self-regulation. Attentiveness is suggested to allow better focus on interaction and language stimuli promoting development (Gartstein et al., 2008). Early self-regulatory ability by allocating attention, on the other hand, is thought to create more instances of interaction (Gartstein et al., 2008). Additionally, a more regulated emotional state may leave cognitive resources free for communication (Bloom & Capatides, 1987). Similar to positive emotionality, self-regulation is typically reported as being positively related to expressive (Dixon & Smith, 2000) and receptive (Dixon & Smith, 2000; Morales et al., 2000) language, including early syntax (Bruce et al., 2022; Spinelli et al., 2018), early communicative skills (Gartstein et al., 2008; Peterson et al., 2017) and gesturing (Ollas-Skogster et al., 2023) in infancy and toddlerhood. The first dimensions of self-regulation are known to appear during the latter half of the first year (Rothbart & Bates, 2006). However, it is also known that self-regulation develops over a long period of time, with rapid growth in self-regulatory abilities taking place after infancy (Rothbart et al., 2004),

leading to less inter-individual stability in self-regulation during the first years of life (Putnam et al., 2008). Consequently, results of previous studies have differed depending on the child or infant age and the communicative outcome reported (e.g. Bruce et al., 2022; Spinelli et al., 2018). Some studies also report null associations between early self-regulation and communicative skills (Karrass & Braungart-Rieker, 2003). In line with these challenges, in our previous work, we only found associations between self-regulation assessed at 12 months of age and gesturing at 14 months of age, not with the earlier measure of self-regulation at 6 months. Neither did any of these self-regulation measures in infancy predict vocabulary at 14 nor 30 months (Ollas-Skogster et al., 2023). Similarly, Bruce et al. (2022) found that self-regulation only was associated with expressive skills (vocabulary and early syntax) concurrently at 24 months, not longitudinally when self-regulation was assessed at 10 months. In contrast, they found no association between self-regulation and gesturing at 10 months (Bruce et al., 2022).

In contrast to positive emotionality and self-regulation, different hypotheses regarding mechanisms behind possible associations between negative emotionality and communicative development are suggested. Those arguing that negative emotionality is negatively related to communicative development state that a more aroused emotional state, positive or negative, taxes the attentional resources available for communication (Bloom & Capatides, 1987). Others suggest that emotionality of both positive and negative quality is effective in initiating and maintaining interaction and thus promotes language learning, and thereby expect negative emotionality to have positive associations with communicative development (Moreno & Robinson, 2005).

Like the suggested mechanisms, the empirical findings regarding negative emotionality also differ between studies. Results range from positive (Moreno & Robinson, 2005; Spinelli et al., 2018) and negative (Kubicek & Emde, 2012) associations with expressive language, as well as reports of no significant relations with any communicative outcome (Ollas-Skogster et al., 2023). Associations of different directionality have also been found within the same study, since Bruce et al. (2022) found that 10-month negative emotionality was positively associated with concurrent gesturing, but negatively predicted 24-month sentence complexity. They concluded that negative emotionality may, on the one hand, lead to more initiation of interaction and hence support gesturing, but on the other hand, as negative emotionality may relate negatively to amount and quality of lexical input during interaction (Vernon-Feagans et al., 2008), it can ultimately have a negative influence on toddler sentence complexity (Bruce et al., 2022).

Taken together, the current understanding of early associations between temperament and communicative development is limited in several aspects. First, most of the findings are based on studies with small or moderate sample sizes, resulting in limited statistical power and generalizability of results.

Second, most research in the field of temperament and communicative development has focused on development of vocabulary, leaving associations between temperament and other dimensions of communication understudied. One example is early gesturing. This early-emerging dimension of communication is strongly related to later language development (Iverson & Goldin-Meadow, 2005; Kuhn et al., 2014). Some studies suggesting gesturing seems to indeed be related to early temperament are starting to emerge (Bruce et al., 2022; Ollas et al., 2020; Ollas-Skogster et al., 2023; Salvadori et al., 2024), but offer inconclusive findings regarding with which temperament traits associations exist. More specifically, Bruce et al. (2022) found positive associations between both positive and negative emotionality and gesturing, but no relation with self-regulation at 10 months, whereas we found gesturing at 12 months to be positively associated with positive emotionality at 6 and 12 months and aspects of self-regulation at 12 months, but not negative emotionality (Ollas et al., 2020; Ollas-Skogster et al., 2023). Similarly, studies exploring associations between temperament and early syntax are underrepresented. However, some of the studies involving syntax measures in toddlerhood indeed suggest this dimension of language may be more related to temperament than vocabulary (Bruce et al., 2022). Consequently, studying these associations further in a larger sample is warranted.

Third, the current literature fails to provide conclusive findings regarding how temperament traits are related to different aspects of communicative development over the earliest years. Studies disagree particularly regarding negative emotionality, presenting both negative and positive associations and null findings (Bruce et al., 2022; Kubicek & Emde, 2012; Moreno & Robinson, 2005; Ollas--Skogster et al., 2023). Also, regarding self-regulation, associations seem to depend on age of assessment (Bruce et al., 2022; Ollas--Skogster et al., 2023). We hypothesize that the inconsistency in results is due to changes in the relationship between dimensions of temperament and language development over the course of development. Thus, more studies using several age points across infancy are needed to gain further understanding of when associations appear and how they possibly change over time.

1.2. The current study

The aim of the current study was to extend our previous study on associations between temperament and communicative development in infancy in the FinnBrain pilot sample (Ollas et al., 2020) using 1 the finalized, larger cohort sample that was not available at the time of the previous study and 2) a wider spectrum of communicative gestures and 3) by adding measures of vocabulary and syntax in toddlerhood as communicative outcomes. Specifically, the current study aims to extend the limited knowledge of associations between infant temperament and preverbal gesturing, which remains a less studied aspect of communicative development. Altogether, we investigate the associations between the infant temperament factors positive emotionality, negative emotionality and emerging self-regulation at 6 and 12 months and verbal and preverbal communicative skills (gesturing and receptive vocabulary at 14 months, expressive vocabulary and syntax at 30 months) in infancy and toddlerhood.

Based on the existing literature and our previous study (Ollas et al., 2020), we hypothesized that infant positive emotionality and self-regulation would be positively associated with all communicative skills across infancy and toddlerhood. We did not set any hypothesis for associations between negative emotionality and communicative development as such associations were not present in our previous study. We expected relations to be stronger with communicative gesturing than with receptive vocabulary in infancy in correspondence with our previous study.

2. Method

2.1. Participants

The participants of the study were families taking part in the FinnBrain Birth Cohort Study in Finland (Karlsson et al., 2018). The cohort study is planned in accordance with the guidelines of the Declaration of Helsinki. Written informed consent from caregivers of the children was provided prior to participation in the study. The cohort study protocol has been approved by the Ethics Committee of the Hospital District of Southwest Finland. The sample in the current study is a convenience sample from the whole cohort based on availability of relevant data. The sample included a slightly higher percentage of firstborn children and highly educated mothers compared to the whole cohort sample ($N = 3837$) as reported in Karlsson et al. (2018) but it was similar regarding other demographic characteristics. The sample size ($N = 1200$ at 14 months and $N = 1039$ at 30 months, overlap between the samples: $n = 789$) is large compared to most prior studies in the field. Prematurely born infants were excluded from the sample (infants born at <37 gestational weeks: $n = 55$ at 14 months and $n = 50$ at 30 months). The participants were monolingual Finnish-speaking children. Families reporting over 20 % exposure to a language other than Finnish were excluded. Cases were chosen for analyses depending on availability of communication development data. Demographic characteristics of the sample are presented in Table 1.

2.2. Procedures

Families were recruited during the first trimester at maternal welfare clinics by personal contact with a research nurse. Information about the families was collected during gestational week 14. Data of child biological sex assigned and gestational age at birth was retrieved from the wellbeing services county of Southwest Finland (VARHA) records from the maternity ward. The mothers completed reports on infant temperament when the child was 6 and 12 months of age. The questionnaires regarding communicative development were completed by the mother when the child was 14 months and 30 months of age.

2.3. Measures

2.3.1. Communicative development

Communicative development was assessed utilizing the Mac-Arthur-Bates Communication Development Inventories (CDI) (Fenson, 1994; Lyytinen, 1999), which is a parent report for assessing infant and toddler language and communication. The Words and gestures-version (CDI-WG) was used at 14 months and the Words and sentences-version (CDI-WS) at 30 months. The CDI-WG for infants contains one section for Actions and gestures, with five subcategories: first communicative gestures, games and routines, actions with objects, pretending to be a parent and imitating other adult actions. For first communicative gestures the reporter checks whether the gesture in question is used often, sometimes or not at all by the infant, and for the remaining subcategories reports whether the gesture/action is used or not. In our previous study (Ollas et al., 2020), only the subcategory ”first communicative gestures” was used, but in the current study the concept of gesturing also involved the symbolic play behaviors (McDonald’s ω for Actions and gestures = 0.83). From the CDI-WG at 14 months we also used the receptive vocabulary measure containing a comprehensive list of common words where the reporter checks whether the infant is perceived to understand the word in question or not ($\omega = 0.97$). From

Table 1
Demographic characteristics of the samples.

	14 months ($n = 1200$)			30 months ($n = 1039$)		
	Mean (*SD*)	%	Range	Mean (*SD*)	%	range
Child characteristics						
Sex assigned at birth, girl		47.2			47.7	
First-born		52.3			53.6	
One sibling		30.7			28.6	
≥ 2 siblings		12.1			12.7	
Data missing on siblings		4.9			5.1	
Twin		.8			.8	
Gestational age at delivery	40.0 (1.22)		37.0 – 42.6	40.0 (1.22)		37.0–42.4
Family characteristics						
Maternal educational level						
University degree		39.8			37.8	
Polytechnic/applied university degree		25.8			28.2	
Vocational training/high school/basic education		30.3			29.7	
Data missing regarding maternal education		4.1			4.2	
Maternal age at delivery	30.8 (4.5)		18 – 45	30.9 (4.3)		18 – 45
Paternal age at delivery	32.4 (5.4)		18 – 54	32.4 (5.3)		18 – 54
Child age at questionnaire completion (days)						
Temperament 6mo	195.3 (9.9)		172–290	194.8 (8.51)		172–260
Temperament 12mo	379.4 (9.6)		342–449	379.0 (9.3)		342–430
Communicative skills 14mo	434.8 (22.0)		365–661	433.8 (24.6)		365–806
Communicative skills 30mo	897.0 (11.1)		879–973	897.7 (13.6)		879–1122

the CDI-WS for toddlers we used the checklist of words for assessing expressive vocabulary ($\omega = 0.99$), as well as the number of morphemes in the three longest reported phrases used by the toddler for calculation of maximal utterance length (M3L).

2.3.2. Infant temperament

For the current study, we used the Infant Behavior Questionnaire – Revised Short Form (IBQ-R, Gartstein & Rothbart, 2003; Putnam et al., 2014) at 6 and 12 months of age for temperament assessment. The IBQ-R short form is a 91-item parent report that contains 14 subscales forming three factor dimensions: approach, vocal reactivity, high intensity pleasure, smiling and laughter, activity level and perceptual sensitivity form the factor positive emotionality (McDonald's ω for 6- and 12-month measures for both subsets of data = 0.85–0.88), sadness, distress to limitations, fear and falling reactivity form the factor negative emotionality ($\omega = 0.82$–0.85) and low intensity pleasure, soothability, cuddliness and duration of orienting form the factor self-regulation ($\omega = 0.82$–0.83). The parent is instructed to assess the infant's behavior in a variety of everyday situations over the past week. The assessment is done by rating how often the infant has displayed a certain behavior by choosing an alternative from a 7-point scale.

2.3.3. Covariates

Factors previously found to be associated with child language and communicative development – child biological sex assigned at birth, gestational age, SES and maternal psychological distress (Fenson et al., 1994; Hoff, 2006; Reck et al., 2018; Snijders et al., 2020; Sohr-Preston & Scaramella, 2006) – were chosen as covariates in the study. Maternal education level has been shown to be the best SES-predictor of maternal language use with the infant (Vernon-Feagans et al., 2008), and was hence chosen in the current study as a covariate representing SES. Mothers provided information regarding educational level during the first trimester of pregnancy, and the data was coded categorically as follows: 1 = higher secondary education (high school-level or vocational training), 2 = polytechnic degree or 3 = university degree. Maternal psychological distress was chosen considering it is of particular interest in the FinnBrain cohort study design (Karlsson et al., 2018) and as it is known to affect the reporting of temperament traits and child language (Durbin & Wilson, 2012). A maternal psychological distress composite score was calculated by standardizing and summing scores of mother-reported postnatal depressive symptoms (the Edinburg Postnatal Depression Scale (EPDS) (Cox et al., 1987) at 12 months postpartum) and anxiety symptoms (the anxiety subscale from the Symptom Checklist – 90, (Derogatis et al., 1973) that was only available at 6 months postpartum). This score was used as a continuous covariate in analyses.

2.4. Data analysis strategy

Analyses were carried out using R Statistical software (v4.3.2, R Core Team, 2023). All temperament variables, the 14-month gesturing and 30-month mean length of utterance variables were considered normally distributed by visual inspection. After square root transformation, the distribution of the 14-month receptive vocabulary variable was considered close enough to normal. Expressive vocabulary at 30 months of age was skewed due to an expected ceiling effect of the measure (Fenson et al., 1994) and deviated from the normal distribution even after transformation. Due to this non-normality, Spearman's rank correlation coefficient was used for zero-order correlations. Correlations were calculated using Hmisc-package (Harrell, 2024) and visualized using the corrplot-package (Wei & Simko, 2021). Additionally, regression models were built differently for the 30-month vocabulary outcome, as described later in the following paragraphs.

In the 14-month dataset, information was missing regarding temperament (6.3–10.9 % missing), maternal postpartum psychological distress (1.2 %), maternal education level (4.1 %) and gesture use (3.5 %). According to Little's MCAR test, the data was not missing completely at random (MCAR, chi-square = 178.1, $DF = 148$, $p = .046$). Since the non-randomness was assumed to be due to SES-related factors, the data was considered missing at random (MAR) (Enders, 2011; Rubin, 1976). In the 30-month dataset, data was missing regarding temperament (6.9–11.9 %), maternal postpartum psychological distress (1.3 %), maternal education level (4.2 %) and M3L (16.6 %). This data was not MCAR either, according to Little's MCAR test (chi-square = 246.9, $DF = 144$, $p < .001$), but was also considered MAR. As recommended in cases with moderate amounts of data missing and data not meeting the assumption of MCAR (Jakobsen et al., 2017), missing data was handled by multiple imputations. The number of imputations was set to 10 and multiple imputations by chained equations (MICE) was used to handle missing data in regression models (van Buuren & Groothuis-Oudshoorn, 2011). Two separate datasets were imputed, one with complete data on 14-month vocabulary prior to imputation ($N = 1200$), and one with complete unimputed 30-month vocabulary data ($N = 1039$). Results were essentially the same using the original and imputed datasets.

Gesturing, receptive vocabulary and M3L variables were considered suitable for use as dependent variables in regular linear regression models due to the large sample size (Lumley et al., 2002). Models were built using the lme4-package (Bates et al., 2015) and the ggeffects-package (Lüdecke, 2018) was used for data visualization. However, in the case of 30-month expressive vocabulary deviating more strongly from the normal distribution, we modeled temperament traits as a function of expressive vocabulary and covariates instead of vocabulary as a function of temperament and covariates. This approach was chosen as an analytically equivalent option to analyze the conceptual association between infant temperament and toddlerhood expressive vocabulary, although technically modeled in the other direction in order to have a dependent variable with a distribution suited for the analysis. Continuous covariates correlating at a level of > 0.20 with any of the response variables were chosen as covariates in regression models. Continuous predictors were *z*-transformed prior to use in models. Models were built by including chosen covariates in the first model (for the sake of brevity models including only covariates are reported in the Supplements 1–3) and then adding the three temperament variables one by one in the consecutive steps. Separate models for different temperament traits were conducted to avoid multicollinearity. The reported change in adjusted R^2 refers to the change in adjusted R^2 when adding a temperament trait to the model

involving only covariates. Finally, the sex by temperament interaction effects were tested for in all models and reported in cases any significant interaction effects were found. The Benjamini-Hochberg-procedure with alpha level < 0.05 was used to correct *p*-values for multiple comparisons per sets of comparisons for each hypothesis (i.e., for negative emotionality and all communicative outcomes; for positive emotionality and all communicative outcomes, and for emerging self-regulation and all communicative outcomes separately, eight comparisons per hypothesis, and according to the same scheme for the separate sex by negative emotionality/positive emotionality/self-regulation interaction effects and all communicative outcomes separately, eight comparisons per hypothesis). As a post hoc-analysis associations between temperament and a syntax variable consisting of a combination of M3L and parent report of child use of grammatical morphemes and verb conjugation were explored in order investigate whether associations would differ depending on syntax measure.

3. Results

Descriptive statistics regarding the measures in the 14- and 30-month subsamples are displayed in Table 2.

3.1. Zero-order correlations

Zero-order correlations between continuous variables are presented in Fig. 1. Positive emotionality and emerging self-regulation had positive bivariate correlations with all later communicative skills except 30-month M3L. The strongest correlations were with gesturing. Negative emotionality had no significant correlation with any communicative skill. Concerning covariates, maternal postpartum psychological distress correlated with negative emotionality at a level > 0.20 (used as dependent variable in regression models involving 30-month expressive vocabulary) and was hence used as a covariate in regression models. Gestational age correlated at a level of <0.20 with all dependent variables and was hence not used in regression models.

3.2. Temperament and communicative development at 14 months

When controlling for child sex, maternal psychological distress and education, positive emotionality, and self-regulation assessed at both 6 and 12 months were positively associated with gesturing at 14 months of age (estimate for positive emotionality at 6 months = 2.89[95 % CI 2.40–3.39], $p < 0.001$, and at 12 months = 3.09[2.56–3.61], $p < 0.001$, estimate for self-regulation at 6 months = 1.90 [1.38–2.42], $p < 0.001$, and at 12 months = 2.40[1.87–2.94], $p < 0.001$). Associations are depicted in Fig. 2. Full regression model summaries are reported in the supplements (supplements 4 and 5). Positive emotionality explained 10–11 % and self-regulation 4–6 % of the variance in gesturing (i.e. Δ adj. R^2 when adding the temperament trait to the model involving only covariates). Negative emotionality had no significant associations with gesturing (supplement 6).

Similarly, after controlling for covariates, infant positive emotionality and self-regulation at both 6 and 12 months of age were positively associated with receptive vocabulary at 14 months (estimate for positive emotionality at 6 months = 0.79[0.58–0.99], $p <$

Table 2
Descriptive statistics for the measures used in the two separate study samples including communicative outcomes at 14 months and at 30 months. $N_{14mo} = 1200$ and $N_{30mo} = 1039$.

Measure (theoretical range)	*M* (*SD*) original data	*M* (*SD*) imputed data	Range
14-month dataset			
CDI			
Gesture use 14 months (0–65)	36.0 (8.8)	35.9 (8.9)	6 – 63
Receptive vocabulary 14 months (0–380)	121.7 (72.6)		0 – 336
IBQ-R 6 months (1–7)			
Positive emotionality	4.7 (0.7)	4.7 (0.7)	2.5 – 6.6
Negative emotionality	3.0 (0.8)	3.0 (0.8)	1.2 – 6.5
Emerging self-regulation	5.3 (0.6)	5.3 (0.6)	3.0 – 7.0
IBQ-R 12 months (1–7)			
Positive emotionality	5.1 (0.6)	5.1 (0.6)	3.2 – 6.5
Negative emotionality	3.3 (0.7)	3.3 (0.7)	1.5 – 5.5
Emerging self-regulation	5.0 (0.6)	5.0 (0.6)	2.4 – 6.7
30-month dataset			
CDI			
Expressive vocabulary 30 months (0–594)	409.4 (158.0)		0–594
M3L 30 months	8.3 (3.4)	8.3 (3.5)	1–30
IBQ-R 6 months (1–7)			
Positive emotionality	4.7 (0.7)	4.7 (0.7)	2.4–6.6
Negative emotionality	3.0 (0.7)	3.0 (0.8)	1.2–6.0
Emerging self-regulation	5.3 (0.6)	5.3 (0.6)	3.3–7.0
IBQ-R 12 months (1–7)			
Positive emotionality	5.1 (0.6)	5.1 (0.6)	3.2–6.5
Negative emotionality	3.3 (0.7)	3.3 (0.7)	1.5–5.5
Emerging self-regulation	5.0 (0.6)	5.0 (0.6)	3.1–6.6

Note. Overlap between the 14- and 30-month datasets = 789.

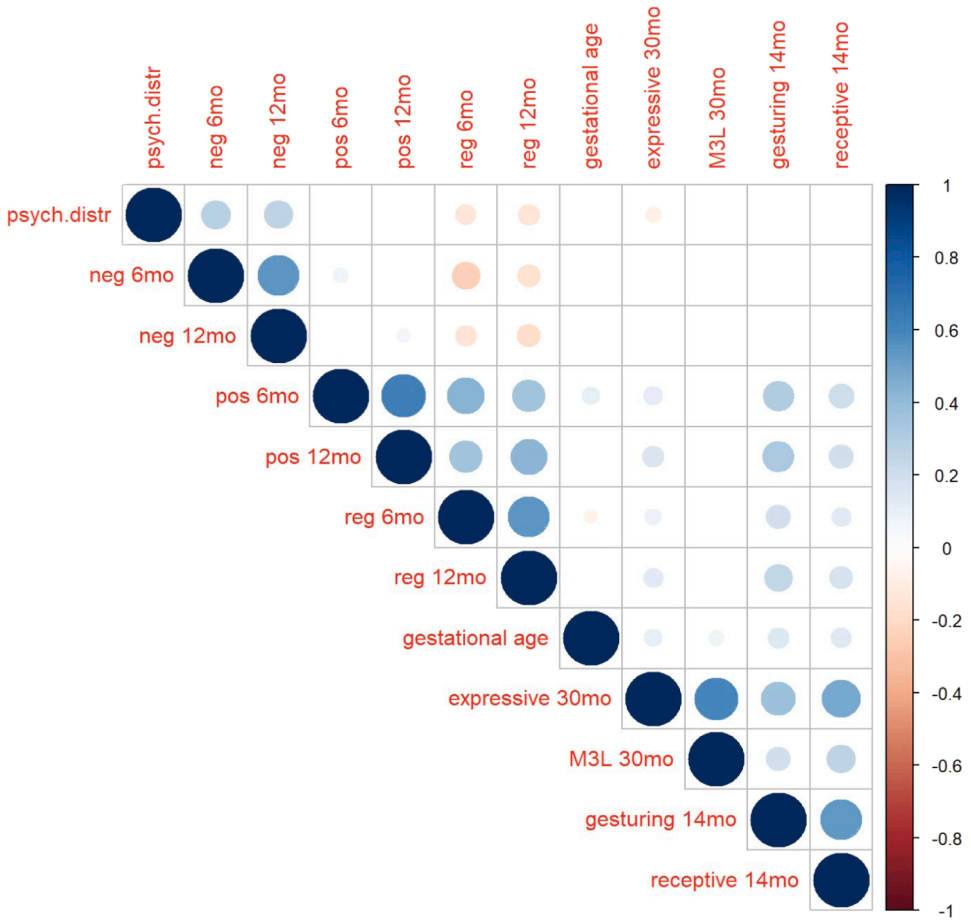

Fig. 1. Zero-order correlations between temperament traits, continuous covariates and communicative skills.
Note. Psych.distr = maternal postpartum psychological distress, neg = negative emotionality, pos = positive emotionality, reg = self-regulation, expressive = expressive vocabulary, M3L = mean length of 3 longest utterances in morphemes, receptive = receptive vocabulary. Only significant correlations ($p < .05$) are represented by a circle.

0.001, and at 12 months = 0.76[0.54–0.97], $p < 0.001$, estimate for self-regulation at 6 months = 0.54[0.32–0.76], $p < 0.001$, and at 12 months = 0.61[0.39–0.82], $p < 0.001$, see supplements 7 and 8). Associations are illustrated in Fig. 3. Positive emotionality explained 4–5 %, and self-regulation 2–3 % of the variation in receptive vocabulary. Negative emotionality had no significant associations with receptive vocabulary (supplement 9).

3.3. Temperament and language skills at 30 months

Although conceptually investigating temperament as a predictor of expressive vocabulary at 30 months, due to expressive vocabulary not being normally distributed we modeled temperament as a function of expressive vocabulary. After accounting for covariates, positive associations between positive emotionality at 6 and 12 months as well as self-regulation at 6 and 12 months and expressive vocabulary at 30 months of age were observed (estimate for vocabulary as a predictor of positive emotionality at 6 months = 0.08[0.04–0.13], $p < 0.001$, and at 12 months = 0.10[0.06–0.14], $p < 0.001$, estimate for vocabulary as a predictor of self-regulation at 6 months = 0.05[0.01–0.09], $p < 0.001$, and at 12 months = 0.06[0.02–0.10], $p < 0.001$, supplements 10 and 11). Associations are illustrated in Fig. 4. Associations between positive emotionality and expressive vocabulary explained 1–3 % of the variance in the model. Corresponding values for self-regulation were 0–1 % with 30-month expressive vocabulary. There were no significant associations between negative emotionality and expressive vocabulary (supplement 12).

In contrast to all other communicative development outcomes, M3L at 30 months of age was not significantly associated with any of the infant temperament traits (supplements 13–15). Post hoc analyses of associations between temperament traits and a syntax measure composed of both M3L and reported use of verb conjugation and grammatical morphemes showed that positive emotionality was significantly associated with this measure of syntax (estimate for positive emotionality at 6 months = 0.16[0.05–0.28], $p = .004$, and at 12 months = 0.13[0.02–0.25], $p = 0.022$) and explained 0–1 % of the variance (supplements 16–19).

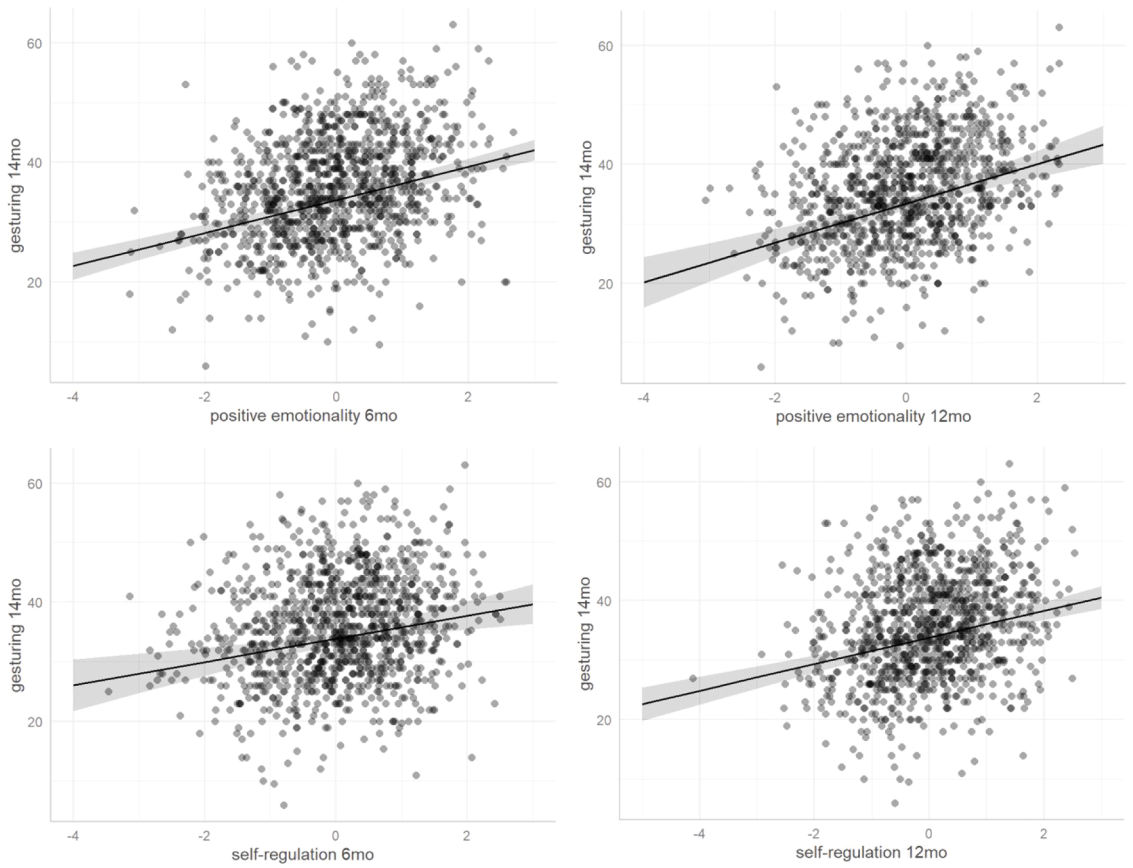

Fig. 2. Associations between positive emotionality and self-regulation at 6 and 12 months and gesturing at 14 months.

3.4. Temperament by sex interaction effects on communicative development

Of the tested temperament trait by child sex interaction effects tested in all models, two were significant.

Namely, there was a significant interaction between 6-month negative emotionality and child sex assigned at birth in predicting child receptive vocabulary at 14 months (estimate = −0.55[−0.97—0.14], $p = .009$, corrected $p = .039$, $\Delta R^2 = 0.00$). Girls with higher reported negative emotionality had smaller receptive vocabularies, whereas for boys, no such association was observed (Fig. 5a). Additionally, there was a significant interaction between 30-month expressive vocabulary and sex in association with 6-month negative emotionality (estimate = −0.16 [−0.26—0.07], $p < .001$, corrected $p = .005$, $\Delta R^2 = 0.01$), suggesting higher negative emotionality in girls was associated with weaker expressive vocabulary, whereas the opposite was true for boys (Fig. 5b).

4. Discussion

In this study, we examined the associations between infant temperament traits of positive and negative emotionality and regulation at 6 and 12 months, and infant and toddler communicative development outcomes at 14 and 30 months. The findings extended those of our previous study (Ollas et al., 2020) in a substantially larger sample, using the whole cohort sample available. In line with our hypotheses and the previous study, positive associations were found between infant positive emotionality and self-regulation assessed at both age points in infancy and all aspects of communicative skills, except syntax measured as maximum sentence length at 30 months. Thus, infants higher in positive emotionality and with better self-regulation as reported by caregivers tend to use more communicative gestures and understand and produce more words in infancy and toddlerhood. The associations were, assessed qualitatively, the strongest with infant gesturing, whereas the effect sizes were more modest with outcomes assessed later in toddlerhood. Similarly, partially in line with our hypothesis and based on the mixed findings from previous studies, we found no significant associations between negative emotionality and any of the communicative dimensions. The sample size of the current study is, to our knowledge, the largest in the field reporting associations between early temperament and communicative development. Thus, our findings considerably strengthen the evidence for the variation in the temperament traits of positive emotionality and emerging self-regulation being relevant for early communicative development.

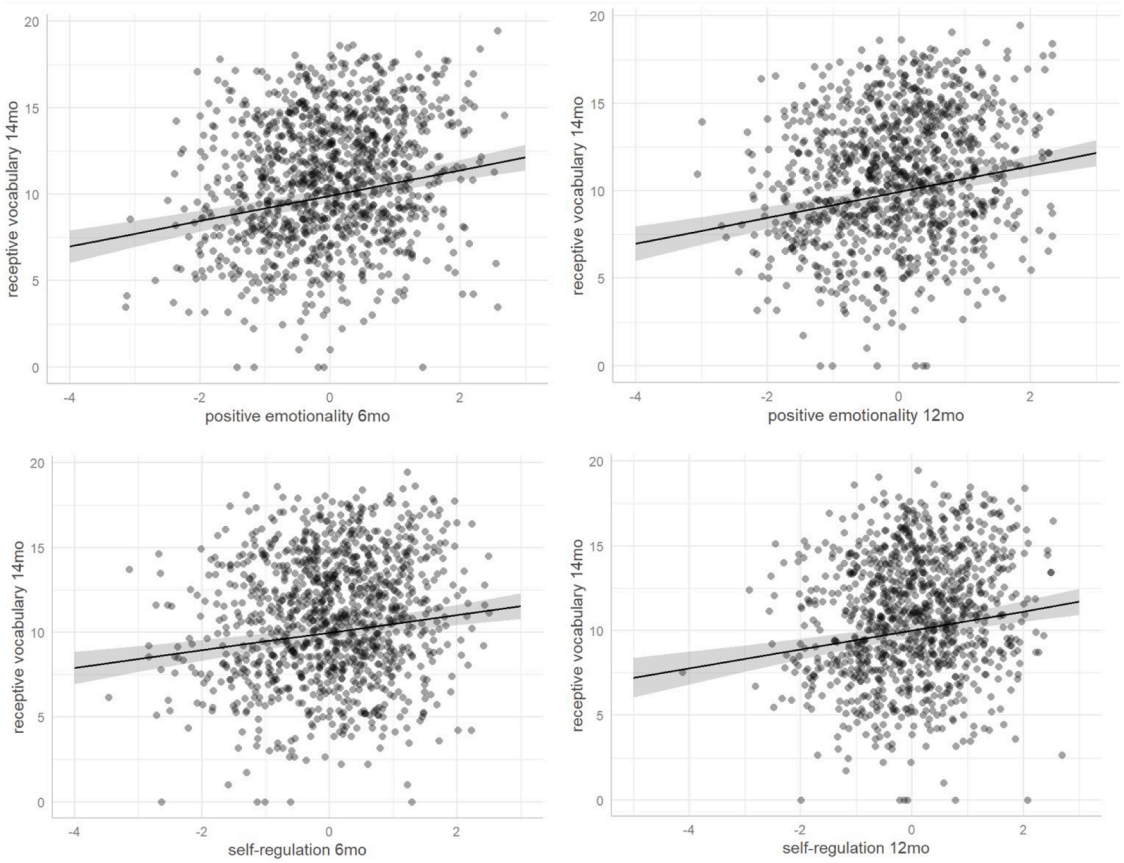

Fig. 3. Associations between positive emotionality and self-regulation at 6 and 12 months and receptive vocabulary at 14 months.

4.1. Temperament and gesturing versus verbal language outcomes

In line with our hypothesis, we found positive associations between the hypothesized temperament traits and early gesturing, a dimension of communicative development that is less studied across the literature. As we also expected, the amount of variance explained by individual temperament traits was, qualitatively assessed, notably larger (5–12 %) for gesturing as compared to verbal language skills (1–5 % and no association with M3L). Although we did not test the difference in effect sizes statistically, the finding is in line with earlier research and thus could reflect an actual difference in the role of temperament as contributor to communicative development. The explanation could lie in some shared modality between temperament and gesturing, since motor activity is involved in both the concept of temperament (Rothbart & Bates, 1998) and gesturing. Additionally, the expression of temperament traits is likely to happen partially using gesturing. For example, positive emotionality may be accompanied by more use of gestures to initiate and maintain interaction and play. In the case of self-regulation, higher gesturing may occur as a consequence of more focused play in infants higher on this temperamental dimension, since part of the gesturing assessed by the CDI is play behavior. Good ability to focus on play may both make play behaviors more observable for adults and encourage joint play supporting development of this type of gesturing.

However, following this logic, associations between negative emotionality and gesturing would also be expected, but were not found in our previous studies (Ollas et al., 2020; Ollas-Skogster et al., 2023), or in the present one. Negative emotionality is also likely to be expressed using gestures, for example to request comforting in a distressed state. However, these situations may require a more restricted repertoire of gestures and the emotional state not be as fruitful for developing more advanced gesturing. Further, the negative emotional tone in an interactive situation may cause parents to attend to the emotional state rather than potential gesturing used by the child, thus not encouraging the gesturing per se. Comparing these results to other studies is challenging since we are not aware of other studies using the exact same assessment points or analyses. In contrast to our findings, Bruce et al. (2022) found associations between negative emotionality and gesturing, but not self-regulation. They had also defined gesturing more restrictively and used only the subcategory First communicative gestures from the CDI-WG, not the gestures involved in symbolic play behaviors included in subsequent subcategories of the Actions and gestures-section. Hence, our findings combined could support the hypothesis that negative emotionality may be more related to a narrower repertoire of gestures communicating a need, as seen in Bruce et al. (2022), whereas self-regulation may be more related to gesturing involving a wider variety of play behaviors, as seen in our study. Another possibility is simply that gesturing is the dominant mode of (expressive) communication preceding verbal skills (Iverson &

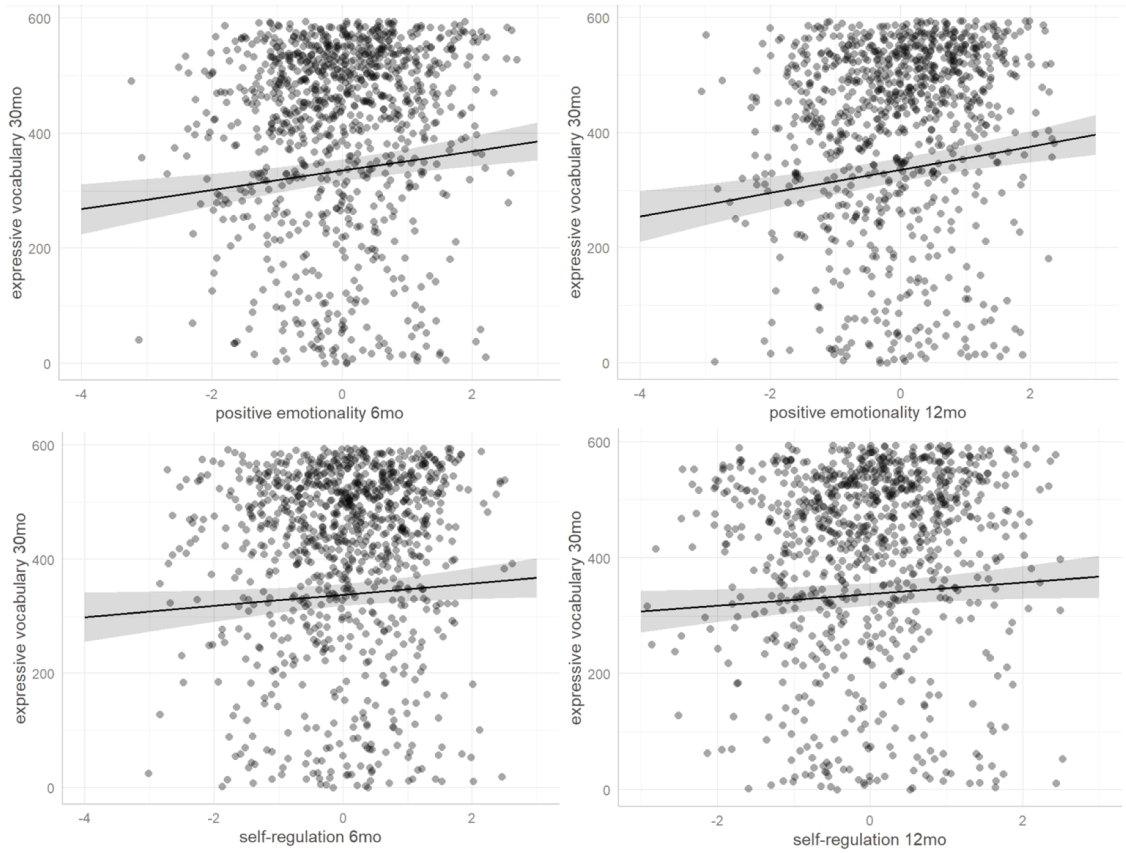

Fig. 4. Associations between positive emotionality and self-regulation at 6 and 12 months and expressive vocabulary at 30 months.
Note. Due to the ceiling effect in the distribution of expressive vocabulary, regression models were built with temperament traits as a function of expressive vocabulary, but for better interpretability, associations are pictured here as theoretically interpreted with expressive vocabulary as dependent variable.

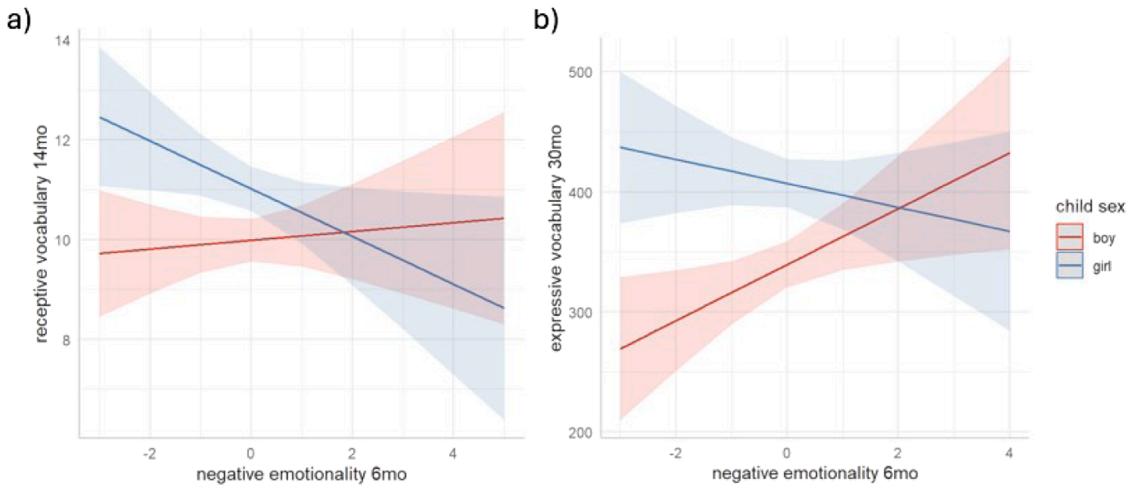

Fig. 5. Associations between 6-month negative emotionality and a) 14-month receptive vocabulary and b) 30-month expressive vocabulary for girls and boys separately.

Goldin-Meadow, 2005) in infancy, and therefore associations with temperament are the most evident with this modality when assessing gesturing and emerging verbal skills concurrently.

To conclude, associations were observed between temperament and both nonverbal gesturing and a variety of verbal measures

ranging into toddlerhood in our study. The fact that the amount of variance explained was largest for gesturing suggests positive emotionality and self-regulation may have a particularly strong positive association with this dimension of communicative skills. Contrary to our hypothesis, no associations were found between temperament traits and early syntax assessed as M3L. Furthermore, as early gesturing is predictive of later verbal language development (Kuhn et al., 2014; Rowe et al., 2022; Rowe & Goldin-Meadow, 2009), these associations imply intra-individual factors associated with gesturing provide an early insight into factors related to language development later on. Longitudinal follow-up of temperament in toddlerhood is needed to further understand the development of these associations across early childhood.

4.2. Positive emotionality and communicative development

The robust finding of positive emotionality being positively associated with communicative development across all modalities further supports the relatively conclusive previous findings (Bruce et al., 2022; Dixon & Smith, 2000; Kubicek & Emde, 2012; Laake & Bridgett, 2014; Morales et al., 2000) and highlights positive emotionality as the temperament trait most clearly related to early nonverbal and verbal communicative skills starting from the first half of the first year of life. In other words, infants with a tendency for positive emotionality and extraversion seem to have an advantage in developing gesturing and vocabulary. This has often been explained as being a result of positive emotionality enhancing and encouraging interaction with caregivers (Bruce et al., 2022) and consequently increasing the amount of language (Laake & Bridgett, 2014) and nonverbal communicative stimulation. However, in our recent study based on data from the same cohort, we found only independent effects of emotional caregiving quality and positive emotionality on communicative development and no moderation effects between the two (Ollas-Skogster et al., 2025). This suggests the relation between positive emotionality and communicative skills can not only be explained by how it influences interaction with the caregiver, at least not when interaction is assessed from an emotional viewpoint. We did not, however, assess caregiver communication. Hence, it is possible that caregiver communication is more intertwined with infant temperament than basic, emotional caregiving. Götz et al. (2024) indeed found an association between positive emotionality and number of conversational turns with the caregiver in early infancy, but unexpectedly caregivers had more conversational turns with infants lower in positive emotionality. Nevertheless, results suggest that temperament can be associated with caregiver communication, although we do not yet fully understand these associations and more research is needed on the mechanisms between the two.

Where previous studies have often reported relations with positive emotionality to differ between communicative modalities (e.g., Bruce et al., 2022; Laake & Bridgett, 2014), our results seem to suggest associations are present with all modalities but are the strongest with gesturing and weaker with toddlerhood language skills. In our study, infant positive emotionality did not reach significance as a predictor of M3L. However, post hoc analyses revealed a small ($\Delta R^2 = 0.00–0.01$), but significant association between positive emotionality and a syntax measure including use of grammatical morphemes and verb conjugation. Additonally, the R^2 change (0.01–0.03) in the model explained by the association between positive emotionality and expressive vocabulary was also very modest. Thus, our results do not motivate claiming a clear difference in the strength of the longitudinal association between infant positive emotionality and toddlerhood expressive vocabulary and syntactic skills. Of course, adding concurrent toddlerhood temperament assessment will add to our understanding of these associations in future studies.

Another interpretation of the result may be that the temperament trait of positive emotionality is associated with a high *use* of communicative skills rather than an advantage in the level of the skills themselves. This may be true especially in this context where communication skills are reported by the parent and assessed informally in everyday situations – possibly the infants higher in positive emotionality are keener to display their acquired communicative skills compared to peers lower in this dimension. For example, an emotionally positive child may utter a newly acquired word more frequently than a child lower in this dimension, influencing the likeliness of parents becoming aware of the addition to the lexicon. In a sample of older children, DeThorne et al. (2011) indeed found that positive emotionality was related to language measures based on whole speech samples, but not based on standardized measures unaffected by talkativeness. On the other hand, as extraversion may be associated with talkativeness and a desire to interact, it is also likely to cause a snowball effect as it simultaneously leads to more exposure to communicative stimuli. Indeed, parents are found to talk more to children who have started to talk themselves (Dailey & Bergelson, 2023). Further studies on the mechanisms behind the relation between positive emotionality and communicative development as well as the relations between parental interaction quality and infant temperament are needed.

To conclude, as results rather robustly suggest positive emotionality is positively related to early communicative development, it may be important to keep in mind that infants lower in positive emotionality may be at risk for having a disadvantage in communicative development and care to provide them with a sufficient amount of high-quality interaction and verbal and communicative stimuli in mutually enjoyable contexts and activities.

4.3. Self-regulation and communicative development

Emerging self-regulation was significantly associated with all measured communicative skills except M3L, indicating infants higher in self-regulation tended to use more gesturing and have somewhat larger receptive and expressive vocabularies. It explained a larger proportion of the variance in gesturing (4–6 %) as compared to verbal skills (0–3 %) where the amount of variance explained was rather small. Contrastingly, the only study we are aware of with corresponding measures by Bruce et al. (2022) found no significant associations between self-regulation and more strictly defined communicative gesturing at 10 months, only concurrent associations with self-regulatory ability and expressive language at 24 months.

The variance explained was smaller in models with toddlerhood expressive vocabulary, which is reasonable considering self-

regulation undergoes radical change at the earliest ages as new abilities come online and skills develop (Putnam et al., 2008; Rothbart et al., 2004, 2007). In light of the typical developmental changes in self-regulation between the ages of 6 and 30 months, it is rather remarkable that a significant, however weak, association can be found between the earliest emerging self-regulatory capacity and vocabulary two years later. Indeed, the associations tended to be stronger for the most proximal assessments of 12-month self-regulation and 14-month communicative skills as compared to the 6-month assessment. Our results align with several previous studies reporting positive relations between early self-regulation and communicative development (Dixon & Smith, 2000; Gartstein et al., 2008; Morales et al., 2000; Ollas et al., 2020; Peterson et al., 2017). The association between early self-regulation and preverbal gesturing is noteworthy. The finding implies self-regulation may especially relate to nonverbal communication, possibly by self-regulation aiding child visual attention to nonverbal communicative stimuli. Whereas words can be overheard and learned while paying attention to something else, nonverbal gesturing requires visual attention. In fact, Vouloumanos and Curtin (2014)) found verbal language skills to be related only to attention to verbal stimuli, not overall attentiveness. Possibly a similar mechanism of differing subdimensions of attention/orienting could explain the stronger associations between overall self-regulation and gesturing in comparison to verbal skills in our study. This hypothesis should be tested in future studies assessing attentiveness to verbal stimuli as well.

Considering the development of self-regulation is thought to be supported by coregulation with the parent (Bernier et al., 2010; Lobo & Lunkenheimer, 2020) and self-regulation in the current study is reported by the parent, it is likely the parent's role in the measure is significant. Consequently, measures of higher co/self-regulation probably entail higher amounts of both verbal and nonverbal interaction as well. Better ability to stay oriented towards interactional stimuli naturally would also benefit development of gesturing and verbal language (Dixon & Smith, 2000). Additionally, the child being engaged in interaction likely encourages adults to interact more and makes interacting enjoyable for both parties.

In sum, our results indicate that associations between self-regulation and communicative skills can be seen starting from 6 months of age. Infant self-regulation is most clearly associated with gesturing but only marginally with toddlerhood expressive vocabulary, indicating a need for follow-up of this developing temperament dimension in toddlerhood to uncover development of associations.

4.4. Negative emotionality and communicative development

Negative emotionality is the temperament trait with the most inconclusive associations with communicative development in the literature. The results of the current study, as well as our other studies within the same cohort (Ollas et al., 2020; Ollas-Skogster et al., 2023, 2025), lend little support for infant negative emotionality being associated with early communicative development. Previous studies that have found associations between negative emotionality and communicative development have explained positive associations with negative emotions often initiating interaction with an adult (Bruce et al., 2022; Moreno & Robinson, 2005), and negative associations with high negative emotionality leading to less attentive resources assigned to interaction (Bloom & Capatides, 1987). If both arguments hold place, the conclusion could be that the benefits and disadvantages of negative emotionality cancel each other out, especially over time, which may explain associations being missing in our study. Although observable already in toddlerhood, vocabulary and self-regulation become increasingly intertwined as verbal skills become more advanced (Vallotton & Ayoub, 2011). Hence, assuming higher negative emotionality would support communicative development by entailing a desire to express and regulate negative emotions, the shift to successfully communicating such emotions verbally could perhaps be expected only later in childhood. Consequently, such associations may only be observable at a later age and require concurrent measures of negative emotionality in toddlerhood. Furthermore, since the proposed association between negative emotionality and communicative skills is explained by regulation of negative emotionality (by initiating interaction for emotional support (Bruce et al., 2022; Moreno & Robinson, 2005), or inversely being unable to interact due to attentional resources being allocated to self-regulation (Bloom & Capatides, 1987)), there is conceptual overlap with the self-regulation temperament dimension. Self-regulation did, in turn, have significant associations with most communicative dimensions in our study. Hence, it is possible that the theoretical associations between negative emotionality and communicative development are, in fact, observed in the self-regulation trait instead. A future study of associations between longitudinal temperament and communicative development profiles based on the same sample as in the present study is planned to examine these associations in a comprehensive manner.

Another possibility is that the effects of infant negative emotionality are dependent on sample characteristics. Our sample was relatively low risk in terms of SES and psychosocial wellbeing. This could result in the parents' communication with their infant being less likely to be influenced by infant negative emotionality, whereas infant negative emotionality may entail a higher risk of leading to harsh parenting or decreased communication in more high-risk samples. In a previous study based on a subsample of the current study sample, we found no interaction effects between emotional caregiving quality and infant temperament on communicative development, suggesting the associations between caregiving and communicative development are not moderated by temperament traits in this sample (Ollas-Skogster et al., 2025). Another study reports relations between negative emotionality and parenting factors to differ depending on family SES (Paulussen-Hoogeboom et al., 2007). More specifically, higher infant negative emotionality is associated with more supportive parenting in high-SES context whereas the opposite is observed in families with low SES (Paulussen-Hoogeboom et al., 2007). Similar SES-related differences could be present when it comes to parental communication. It is also possible associations are conversation partner dependent, since Salvadori et al. (2024) found negative emotionality with fathers only to positively predict the development of gesturing, and our study included mother reports only. Future studies should thus include both parents and diverse family models to further examine the role of negative emotionality among factors related to communicative development.

However, although preliminary, it is noteworthy that we found some tentative evidence for child sex assigned at birth moderating the association between early infancy negative emotionality and communicative development. Namely, high 6-month negative

emotionality was associated with lower receptive vocabulary at 14 months and expressive vocabulary at 30 months in girls only, whereas boys with high negative emotionality at 6 months seemed to have larger expressive vocabularies at 30 months. By contrast, Nozadi et al. (2013) found that higher negative emotionality at 30 months in boys only was associated with lower concurrent expressive vocabulary, but that higher negative emotionality in early toddlerhood was positively associated with expressive vocabulary for both sexes. They hypothesize that early expressions of negative emotionality at an age where communicative and self-regulation skills are rudimentary may be beneficial for communicative development as they are effective in initiating interaction and coregulation. However, high negative emotionality later in toddlerhood when verbal skills and self-regulation are expected to be at a higher level may be more maladaptive (Nozadi et al., 2013). In our sample, this hypothesis seemed to be supported for boys only, whereas very early negative emotionality in girls seemed to have negative associations with later language skills. Possibly social factors explain the sex differences (Huttenlocher et al., 1991) if negative emotional expressions elicit different responses from caregivers depending on child sex. The interaction effects found in the present study were, however, very modest. Although of little clinical relevance due to the small effect sizes, these findings suggest sex differences in relations between negative emotionality and communicative development need further theoretical investigation.

4.5. Strengths, limitations and directions for future research

Strengths of the current study are its sample size, being part of a prospective longitudinal cohort study, the design with repeated measures of both temperament and communicative development, the involvement of all infant temperament dimensions as well as use of a range of communicative development outcomes, including both gesturing and verbal communicative development. Obtaining similar results as in our previous study with the cohort pilot sample further supports robustness of the findings.

However, the study also has limitations that need to be taken into consideration. Assessment of temperament and communicative skills were not conducted at the exact same time points in our study, and temperament was assessed in infancy only. Concurrent temperament and language skill assessment in toddlerhood would be important to gain further understanding of how relations between temperament and communicative skills possibly change over childhood. Considering associations were the strongest between temperament traits and nonverbal communication, future studies should examine such relations at later ages and continue to compare with verbal communication. We are planning future studies with longitudinal language and temperament trajectory data to further illustrate the long-term associations between the two.

Assessment of temperament and communicative development relying on parent reports allowed the large sample size and is considered a reliable and valid method (e.g. Feldman, 2007; Fenson et al., 1994; Komsi et al., 2006), but may nevertheless be considered a limitation due to lack of objectivity. Also, involvement of only mother and not father reports can be considered a limitation since fathers are also frequent interaction partners likely to play a role for infant communicative development (Cabrera et al., 2007). Longitudinal task- and observation-based data of both temperament and communicative development is needed to make more far-reaching conclusions less dependent on possible reporter bias. Studies have indicated associations between temperament and language may depend on parental language input (Spinelli et al., 2018). Thus, controlling this would be important in future studies.

5. Conclusion

The results confirm the findings of our previous, smaller study and highlight positive emotionality and self-regulations as the key temperament traits to positively predict communicative skills across several assessed communicative modalities in infancy and toddlerhood. Gesturing was particularly evidently associated with these temperament traits. Clinically, the results suggesting infant temperament is related to communicative development up until toddlerhood imply a need to take temperament into account in early care, or counselling focused on caregiving, to provide all infants with a sufficient amount of communicative experience for developing gesturing and verbal language skills. More specifically, infants lower in positive emotionality and early self-regulation ability may benefit from more explicit (parental) communicative stimulation and scaffolding to acquire strong early communicative skills.

CRediT authorship contribution statement

Denise Ollas-Skogster: Writing – original draft, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Pirkko Rautakoski:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Anna Kautto:** Writing – review & editing, Methodology, Formal analysis. **Hasse Karlsson:** Resources, Project administration, Funding acquisition. **Elina Mainela-Arnold:** Writing – review & editing, Conceptualization. **Linnea Karlsson:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization. **Saara Nolvi:** Writing – original draft, Supervision, Methodology, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare no conflicts of interest with regard to the funding source for this study.

Acknowledgements

This research has received grants from the Strategic Research Council (SRC) established within the Academy of Finland (#352648,

subproject #352655), the Finnish Cultural Foundation, the Research Council of Finland (#308176, #342728), the Kommunalrådet C G Sundells stiftelse, the Signe and Ane Gyllenberg Foundation, Finnish State Grants for Clinical Research (VTR) and the Emil Aaltonen Foundation.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jcomdis.2025.106564.

Data availability

Access to the FinnBrain cohort data can be acquired by contacting the FinnBrain executive board and PI Prof Linnea Karlsson (linnea.karlsson@utu.fi) to establish research collaboration. Sharing data outside research collaboration is precluded by Finnish national legislation on personal data protection and the ethics regulations of the FinnBrain cohort

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