Neural correlates of phonological processing as predictors of later language development

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Infants are sensitive to *phonology* from birth

Infants' sensitivity to phonology from birth

- *Prosody*: Discrimination of rhythmically different languages
- *Segmental phonology*: Discrimination of native and non-native vowels

Kuhl, 2004; Moon, Lagercrantz, & Kuhl, 2013;
Nazzi, Bertoncini, & Mehler, 1998

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Phonology marks words and grammatical relations

Infants' sensitivity to phonology from birth

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Kuhl, 2004; Moon, Lagercrantz, & Kuhl, 2013; Nazzi, Bertoncini, & Mehler, 1998

Correlation of phonology and linguistic function

- Prosody marks words and word combinations
- Segmental phonology marks grammatical relations

Gleitman & Wanner, 1982; Morgan, Meier, & Newport, 1987; Peters, 1993

→ Bootstrapping = Infants use phonological information as *bootstraps* into words and grammar (as precursors of lexical-semantic and morpho-/syntactic knowledge of their native language)

How to capture early phonological processing

Electroencephalographic (EEG) recordings

ball…ball…ball

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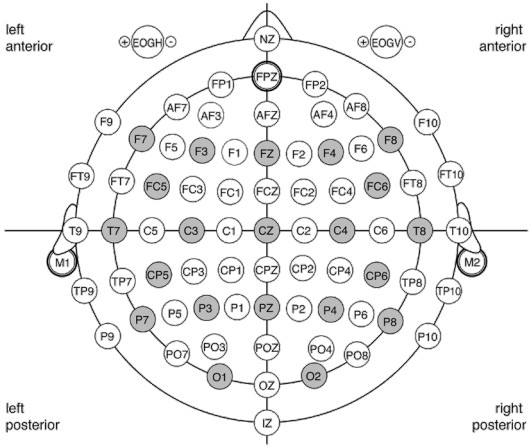
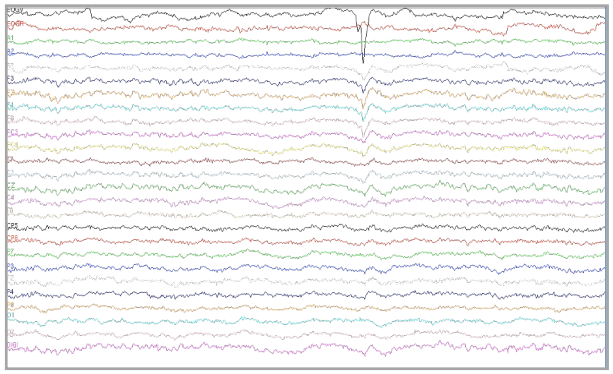


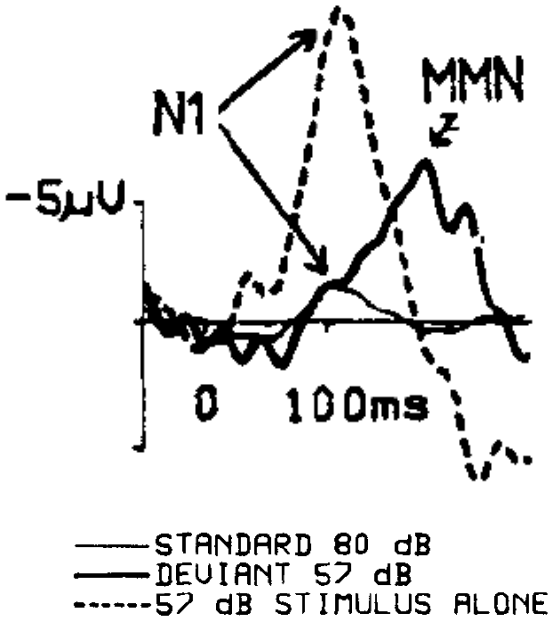


→ Behavior-independent brain measures of speech and language processing

How to capture early phonological processing

***Mismatch negativity* (MMN)**

= Electrophysiological, event-related brain response of (auditory) change detection



Risto Näätänen
Source: https://en.wikipedia.org/wiki/Risto_Näätänen

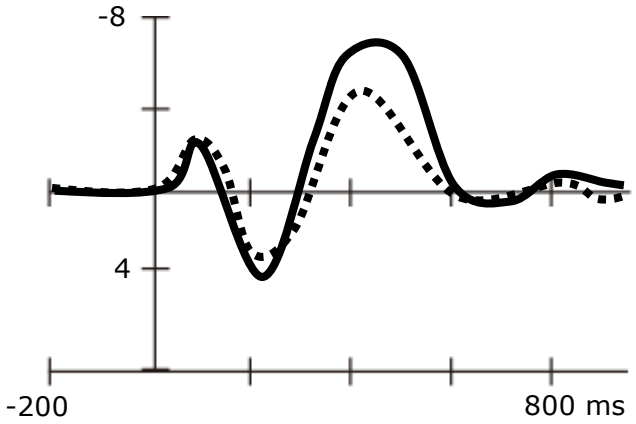
Hillyard et al., 1973; Näätänen, Gaillard & Mäntysalo, 1978; Source: Näätänen et al., 1989

How to capture early phonological processing

Phoneme perception/discrimination

ga ga ga ga Deviants

pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa Standards

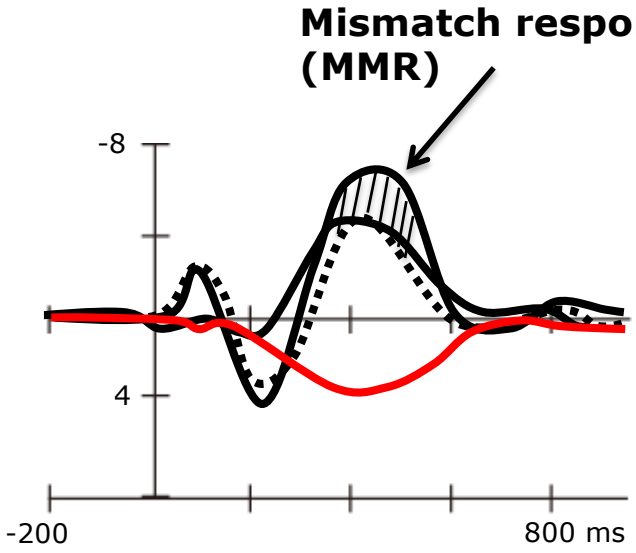


How to capture early phonological processing

Phoneme perception/discrimination

ga ga ga ga **Deviants**

pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa pa **Standards**



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- MMR best visible in the difference wave
- MMR usually negative in polarity

  Adult mismatch negativity, MMN *Näätänen et al., 2007*
- Positive MMRs also observed

  Associated with early development, developmental delay, or difficult discrimination contrasts

  Ahmmed et al., 2008; He, Hotson & Trainor, 2009; Mueller, Friederici & Männel, 2012; Schaadt et al., 2015

Study: Does phoneme perception relate to later lexicon?

Starting from around 8 mo, infants (like adults) behaviorally show a *consonant-bias* in lexical processing; that is, there is a preferential role for consonants over vowels

- Does infants‘ early vowel and consonant discrimination (= developmental trajectory of phoneme discrimination) differentially relate to later lexical skills?

Benavides-Valera et al., 2012; Hochmann et al., 2011; Nazzi & Cuttler, 2019; Nespor et al., 2003

Consonant bias in lexical processing

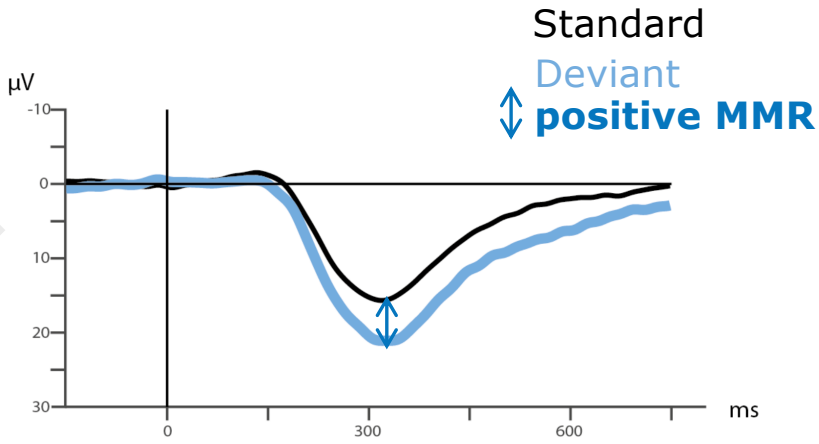
Study: Does phoneme perception relate to later lexicon?

Phoneme perception/discrimination (MMR = mismatch response):

Multi-feature paradigm with semi-synthesized syllables

- Standard syllable: /ba/
- Consonant deviant: /ga/
- Frequency deviant: /ba+/
- Length deviant: /baa/
- Vowel deviant: /bu/

Consonant MMR
Vowel MMR



Näätänen et al., 1978; Cheng et al., 2015; Trainor et al., 2003

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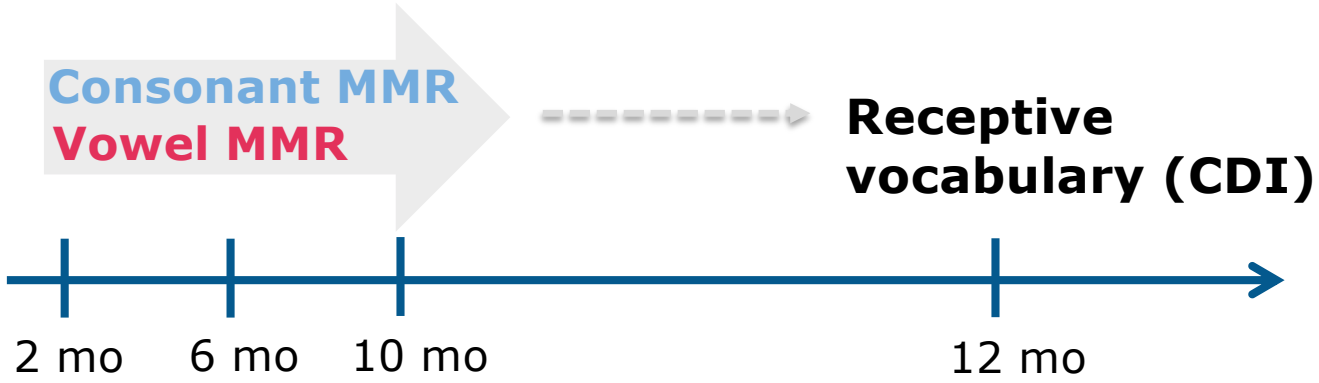
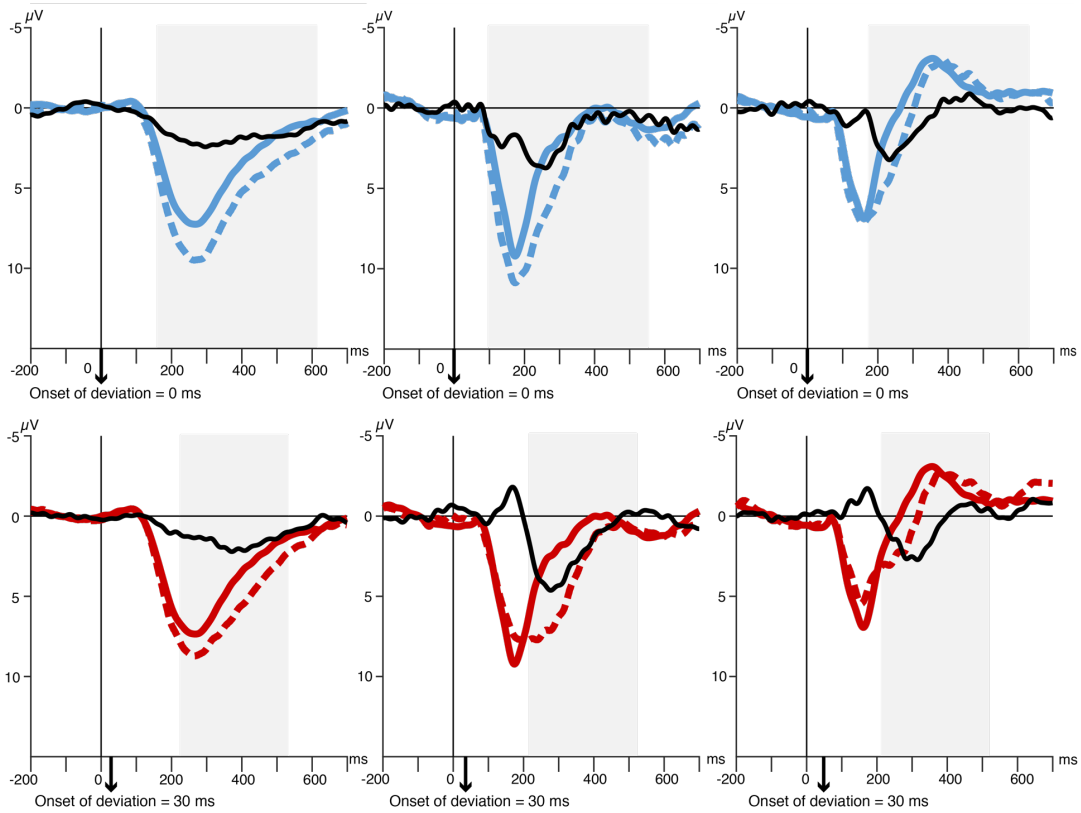
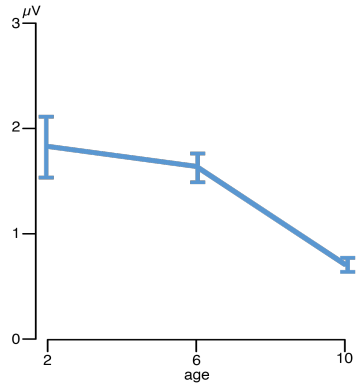


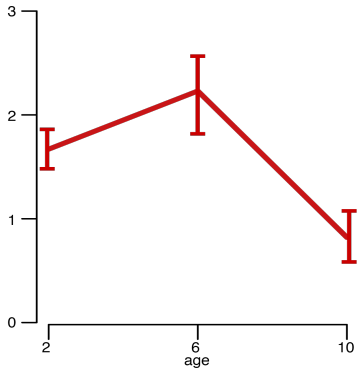
Grimm & Doil, 2000

Phoneme discrimination changes across age

2 mo (*n* = 50) **6 mo** (*n* = 53) **10 mo** (*n* = 51) **MMR trajectories**







MMR =
Deviant–Standard

Trajectories:

Estimation of intercepts and slopes by latent growth curves

Standards
Consonant deviants
Vowel deviants
Difference wave

Schaadt, Werwach*, Obrig, Friederici, & Männel, 2023, Child Dev*

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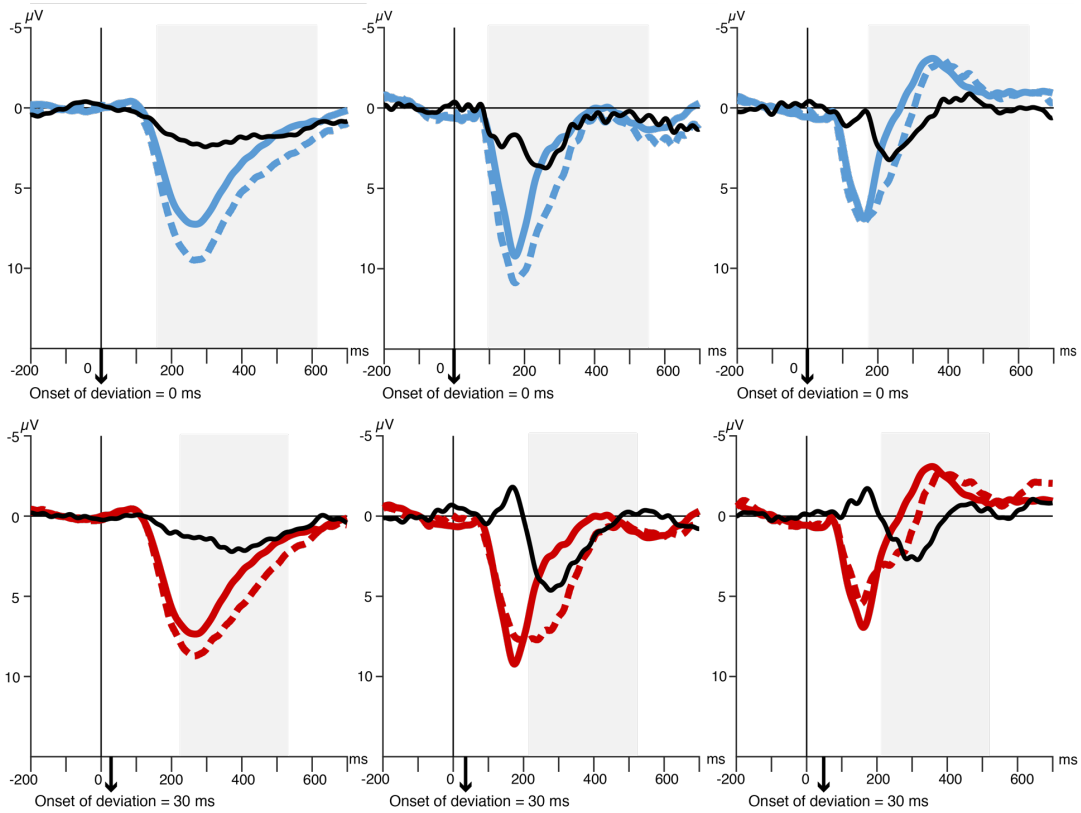
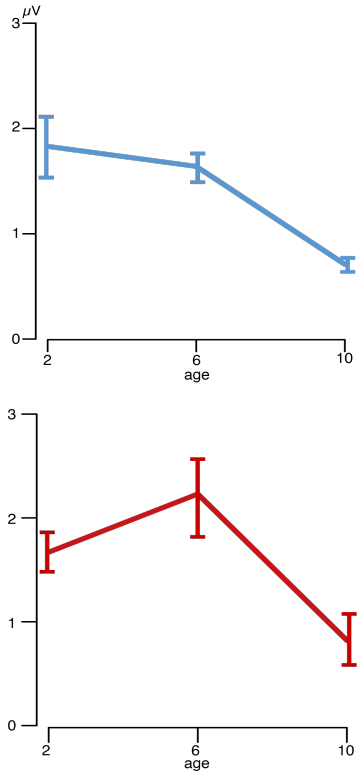


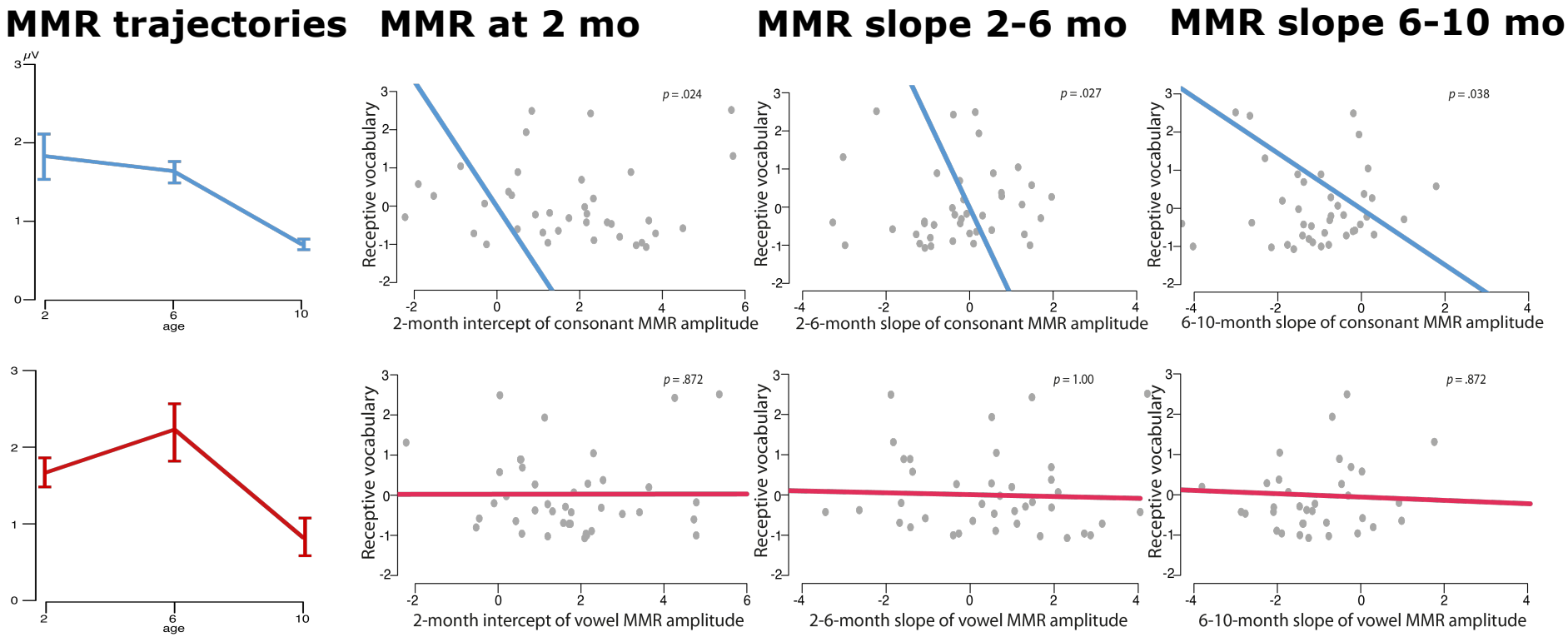


MMR decreases to less positive (more negative) amplitudes
→ maturation of vowel & consonant perception across 1st year of life

Standards
Consonant deviants
Vowel deviants
Difference wave

Schaadt, Werwach*, Obrig, Friederici, & Männel, 2023, Child Dev*

Consonant perception (trajectory) relates to lexicon



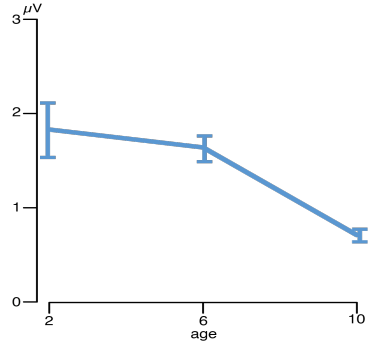
Consonant
Vowel

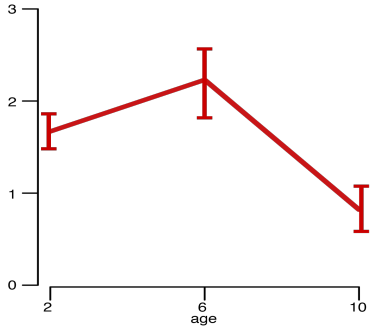
Less positive consonant MMR and stronger longitudinal changes (towards less pos/ neg) relate to larger vocabulary at 12 mo

Schaadt, Werwach*, Obrig, Friederici, & Männel, 2023, Child Dev*

Consonant perception (trajectory) relates to lexicon

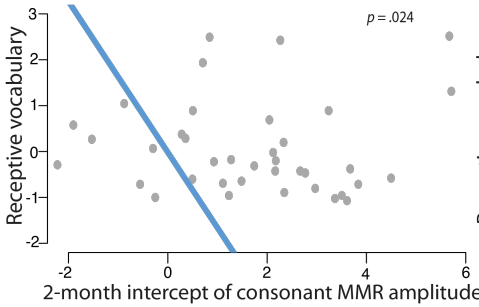
MMR trajectories



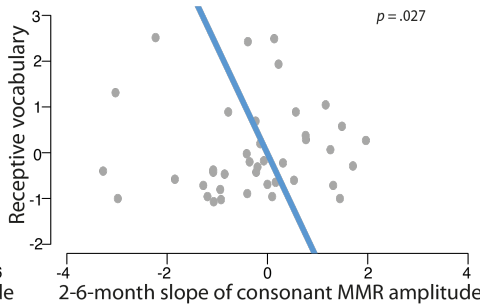


Consonant
Vowel

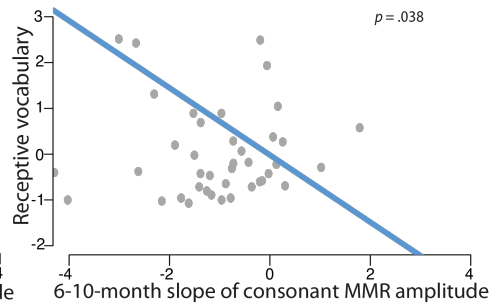
MMR at 2 mo



MMR slope 2-6 mo



MMR slope 6-10 mo



Consonant, but not vowel perception, relates to infants' later vocabulary

→ Role of consonant perception for word learning before behavioral onset of consonant-bias in word recognition

Individual differences in longitudinal maturation of consonant perception are informative about lexical acquisition

Schaadt, Werwach*, Obrig, Friederici, & Männel, 2023, Child Dev*

Learning environment:
Maternal postpartum depression and subclinical symptoms

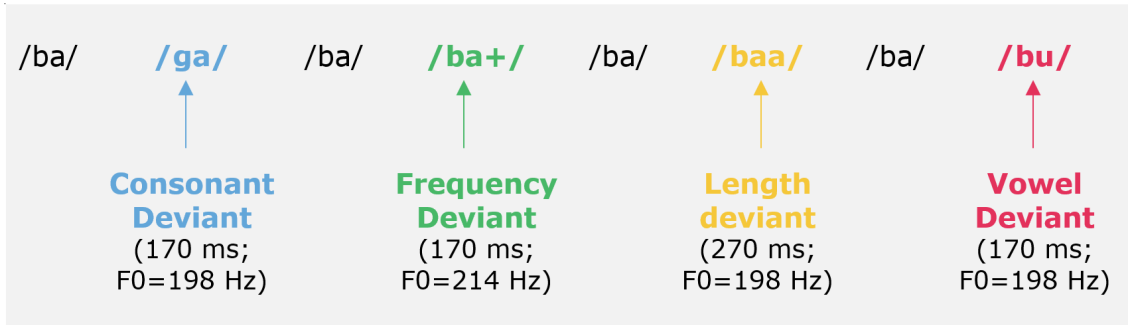
- Global public health issue
  → Prevalence of postpartum depression 10-15%
  Almond, 2009; Brummelte & Galea, 2016
- Low mood and subclinical postpartum depression symptoms in 70% of recent mothers
  → *Baby blues* *Stewart & Vigod, 2016*
- Negative effects not only for mothers, but also their children, for example, regarding language development *e.g., Liu et al., 2017*

→ Is maternal depressed mood postpartum at *subclinical levels* associated with the maturation of infant speech perception?

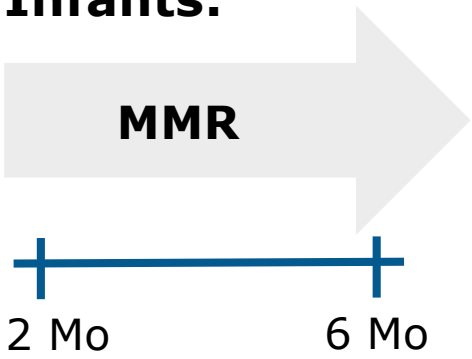
Study: Maternal mood and infant speech perception

Multi-feature paradigm with syllables

- Standard syllable: /ba/
- Consonant deviant: /ga/
- Frequency deviant: /ba+/
- Vowel length deviant: /baa/
- Vowel deviant: /bu/



Infants:



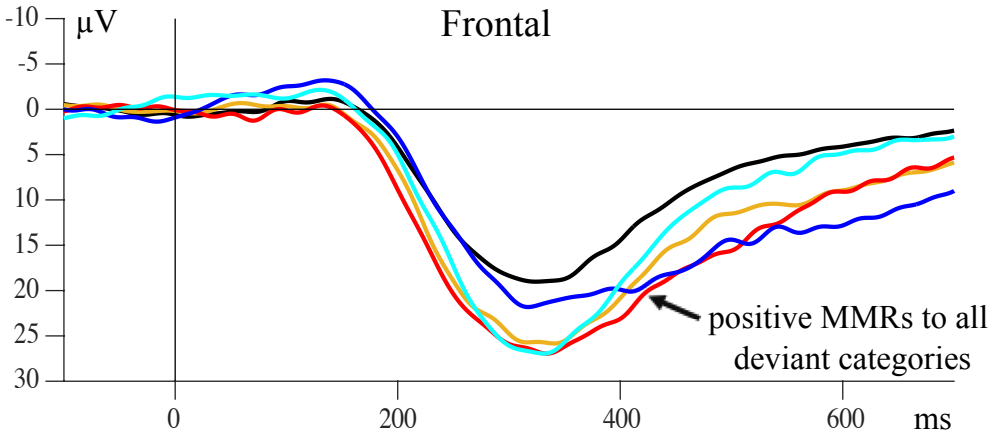
Mothers:

- Postpartum mood at infant-age of 2 mo: *Edinburgh Postnatal Depression Scale, EPDS* *Cox, Holden, & Sagovsky, 1987*
- Control: *Perceived Stress Scale, PSS-10* *Klein et al., 2016*

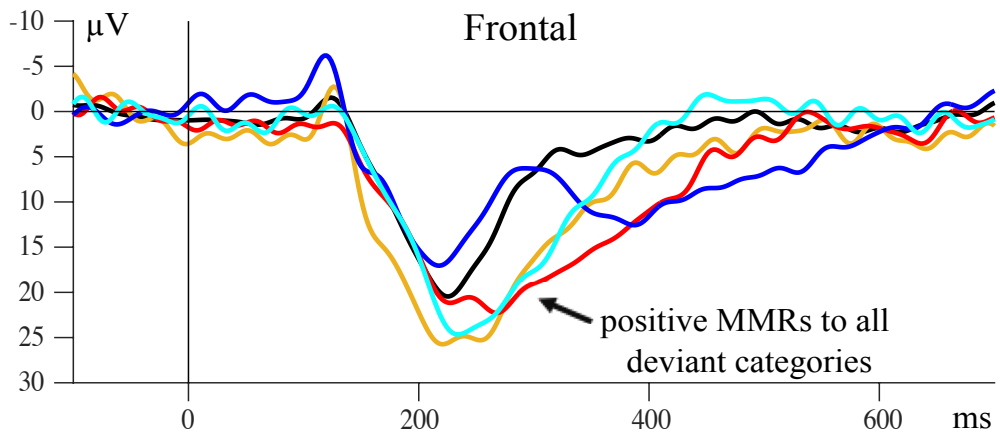
Schaadt, Zido, Obrig, Villringer, Männel, & Sacher*, 2022, JAMA Network Open*

Speech perception at 2 mo and 6 mo

2 mo (*n* = 46)



6 mo (*n* = 36)



- For all phoneme contrasts, significant pos MMR at both ages
- Longitudinal change between 2-6 mo towards less positive (more mature) responses

Standard /ba/
Pitch Deviant /ba+/
Consonant Deviant /ga/
Vowel Deviant /bu/
Vowel Length Deviant /ba:/

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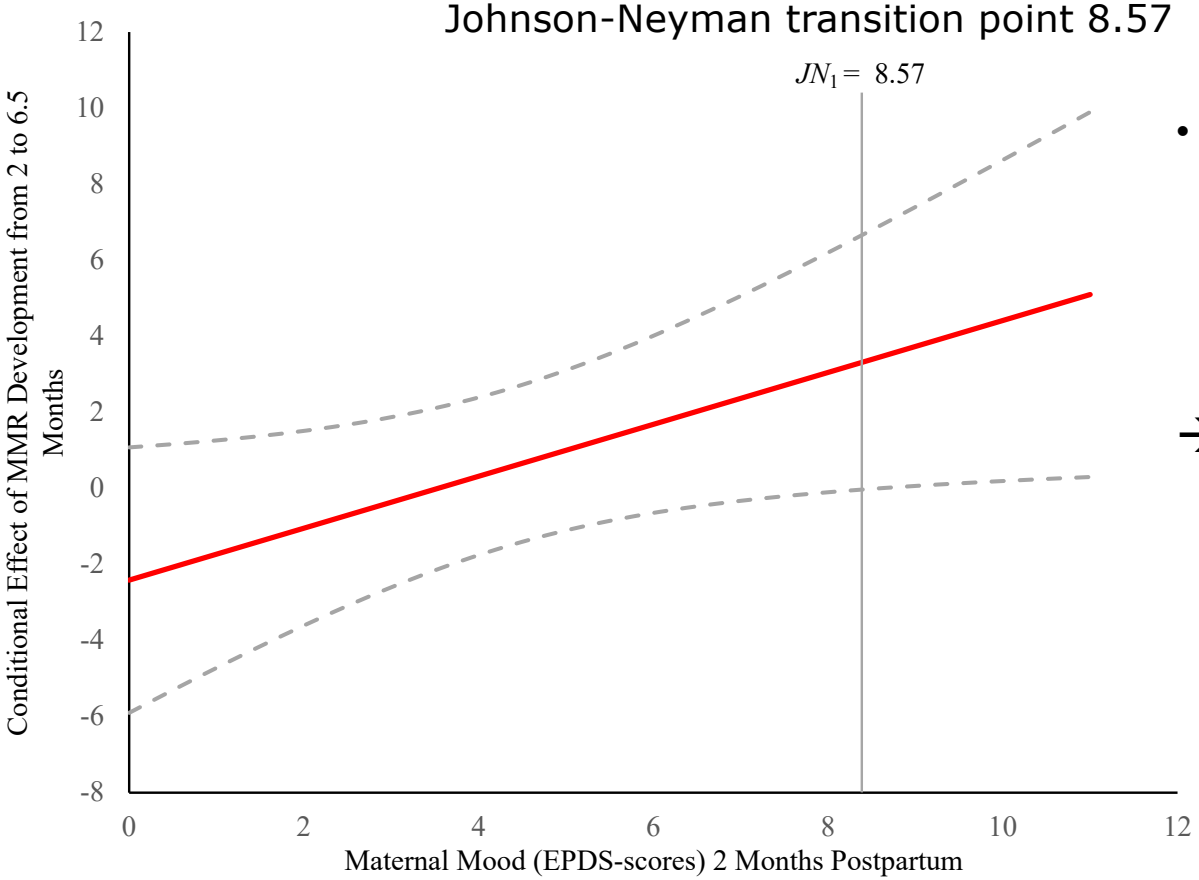
Moderation of maternal mood on infant MMR

Moderation:
Johnson-Neyman transition point 8.57



- Maternal mood (2 mo postpartum) is significantly associated with **syllable pitch MMR** change from 2-6 mo

→ With more subclinically depressed maternal mood (esp. for scores >8.57), MMR development stagnates or even becomes more pos (immature) at age 6 mo

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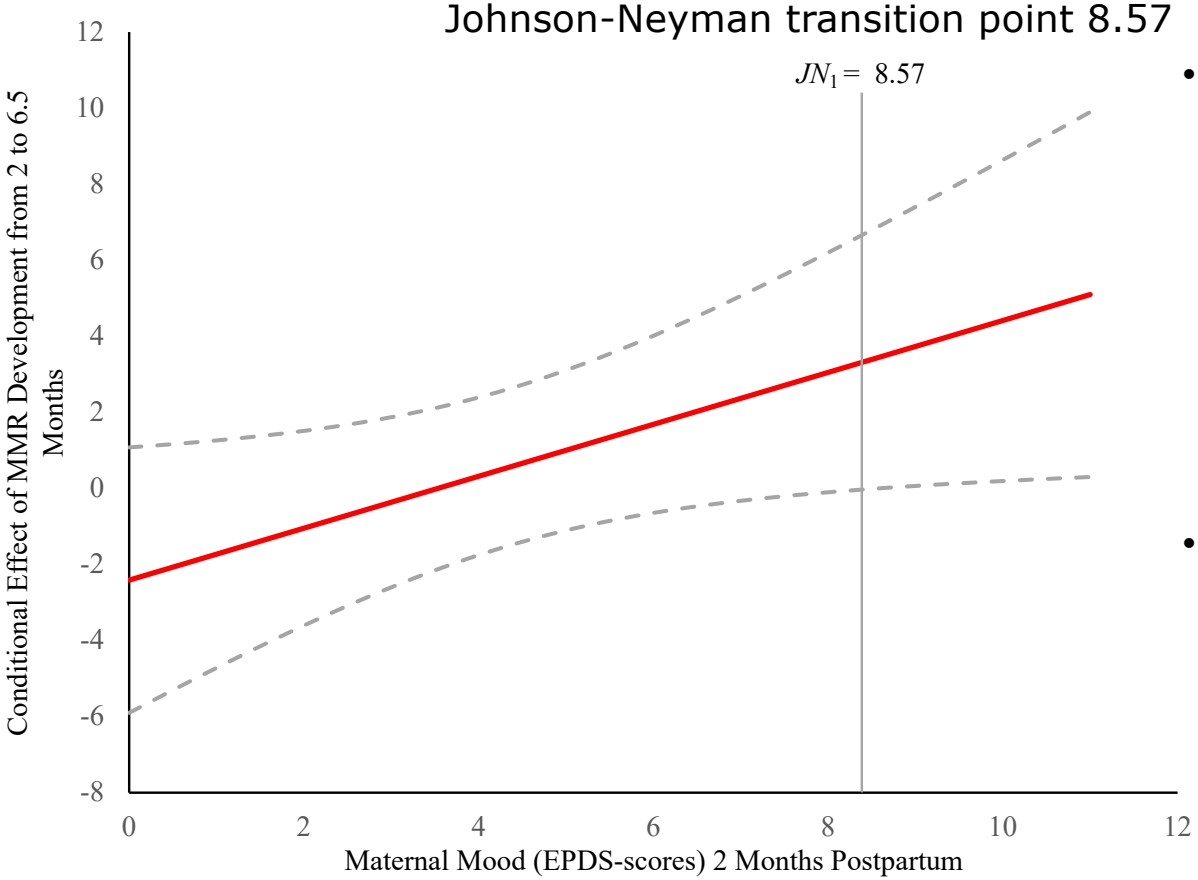
Maternal mood and infant syllable-pitch perception

Moderation analysis:
Johnson-Neyman transition point 8.57



- Less mature *syllable-pitch* perception might result from less pronounced infant-directed speech in mothers with lower mood (see evidence from postpartum depression)
  Kaplan et al., 2001; Porritt et al., 2014
- Prolonged period of positive (immature) MMR during first months is associated with risk of later language difficulties
  Friedrich, Herold, & Friederici, 2009

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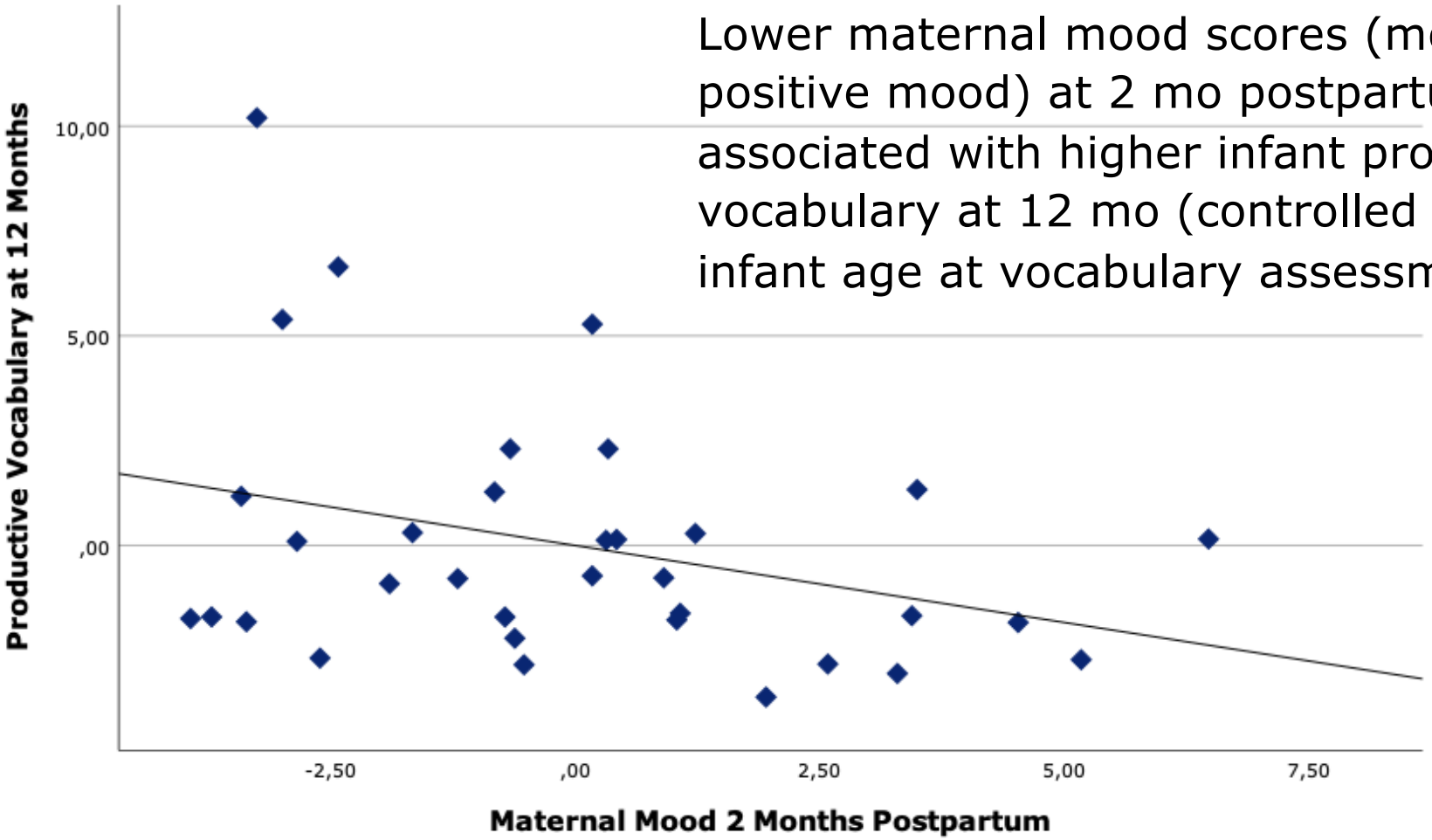
Maternal mood postpartum and later infant vocabulary



Lower maternal mood scores (more positive mood) at 2 mo postpartum is associated with higher infant productive vocabulary at 12 mo (controlled for infant age at vocabulary assessment)

Genetic and neurobiological conditions of learning deficits: Developmental dyslexia

- Specific learning disorder (prevalence of ca. 5% in Germany)
- Significant impairments in the acquisition of reading and spelling skills
  - age-adequate intellectual abilities
  - age-adequate education
  - no neurological or sensory acuity deficits

- **Phonological** processing deficit

  → Problems in representing, storing, and retrieving phonemes

Mann & Libermann, 1984; Snowling, 1998; Schule-Körne, 2017

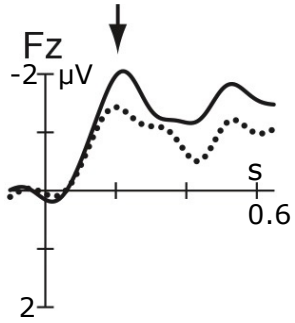
Phonological processing deficit in dyslexia

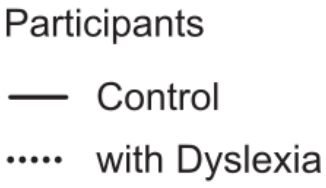
Reduced mismatch responses to phoneme changes in dyslexia

Adults (*n*=30)

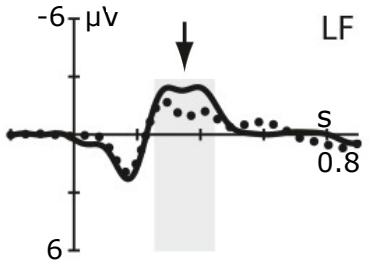
10-yr-olds (*n*=44)

Mismatch response





Mismatch response

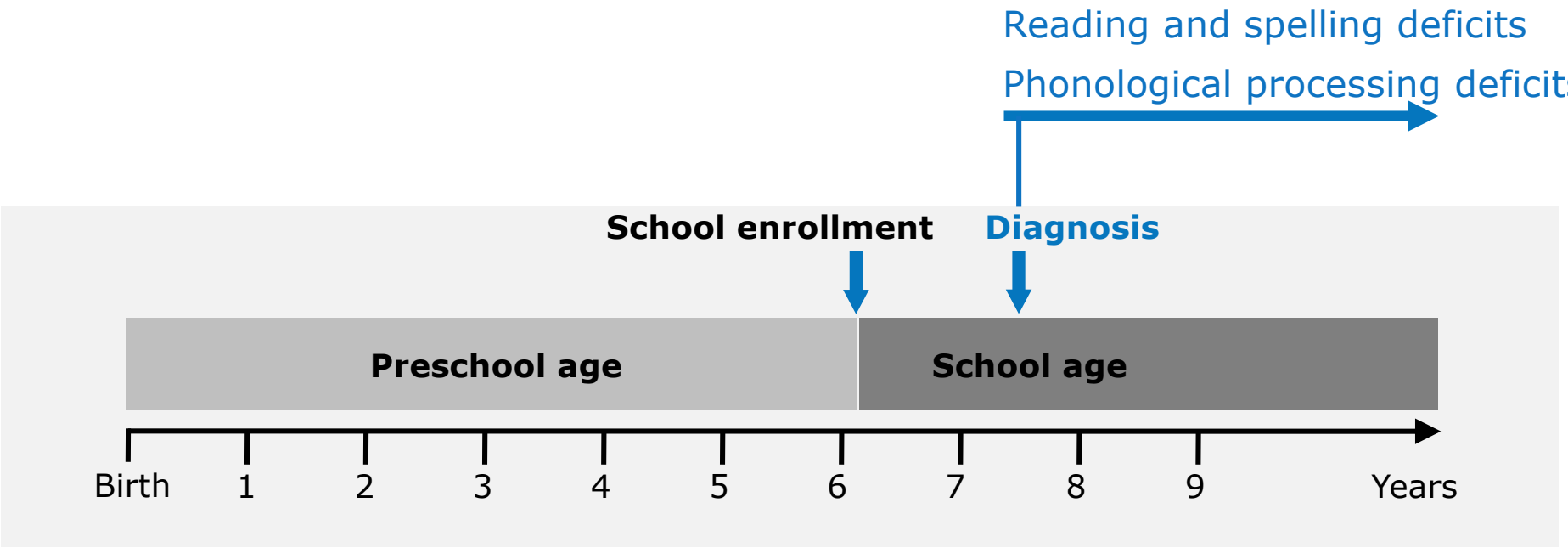


Consonant change (difference waves): /da/ vs. /ga/

Vowel length change (difference waves): /ba/ vs. /ba:/

Cantiani, Lorusso, Guasti, Sabisch, & Männel, Neuropsychologia, 2013; Männel, Schaadt, Illner, van der Meer, & Friederici, 2017, Dev Cogn Neurosci

Phonological deficit: Consequence or cause?



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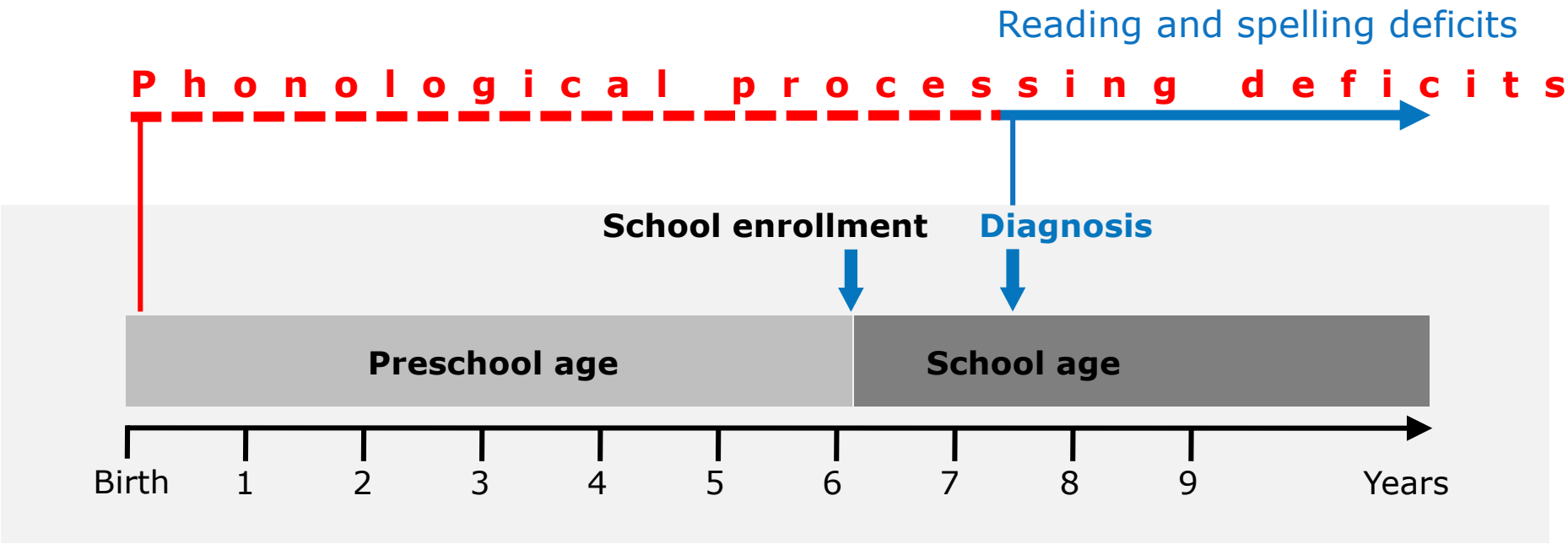


Experimental approach: Longitudinal study of infant phonological processing, with follow-up until school age

see also Lohvansuu et al., 2018; van Zuijen et al., 2013

Longitudinal predictors of developmental dyslexia

R e t r o s p e c t i v e a n a l y s i s

10 yrs (*n*=38)

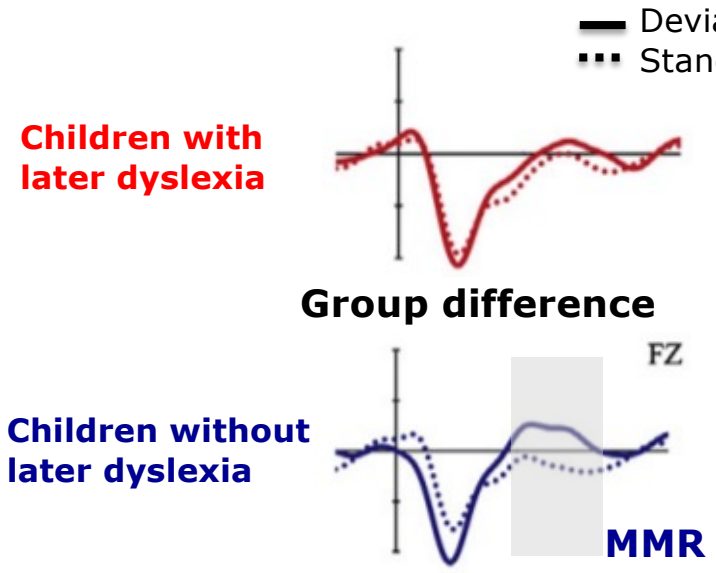
→ Reading and spelling problems

Schaadt, Männel et al., 2015, Res Dev Disabil

Longitudinal predictors of developmental dyslexia

R e t r o s p e c t i v e a n a l y s i s

5 mo (*n*=38)	10 yrs (*n*=38)



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Longitudinal predictors of developmental dyslexia

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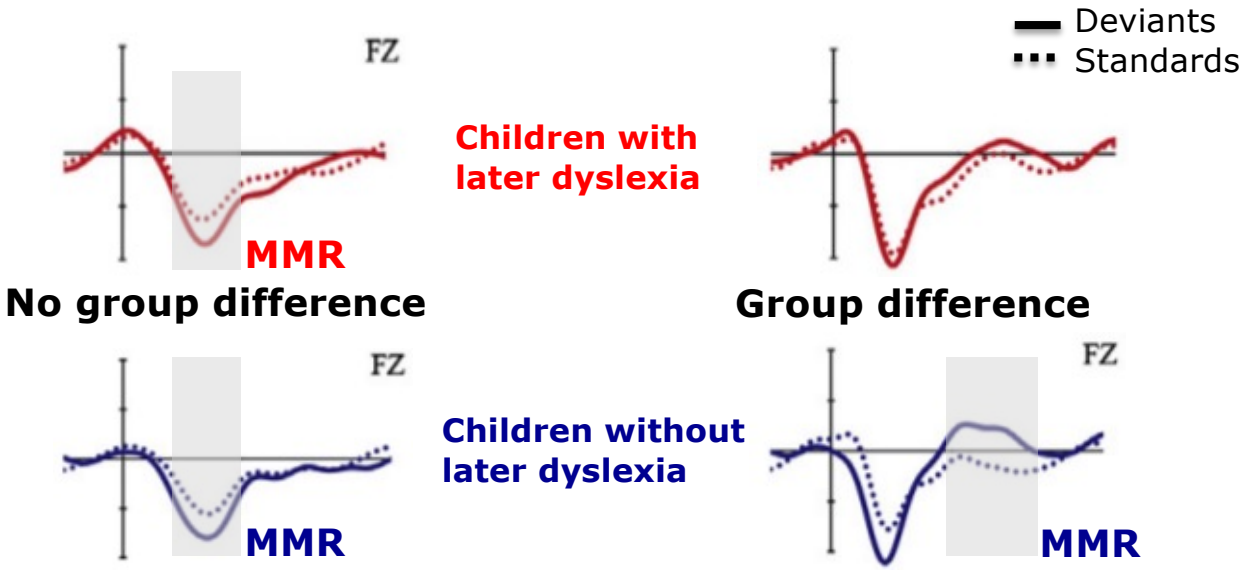

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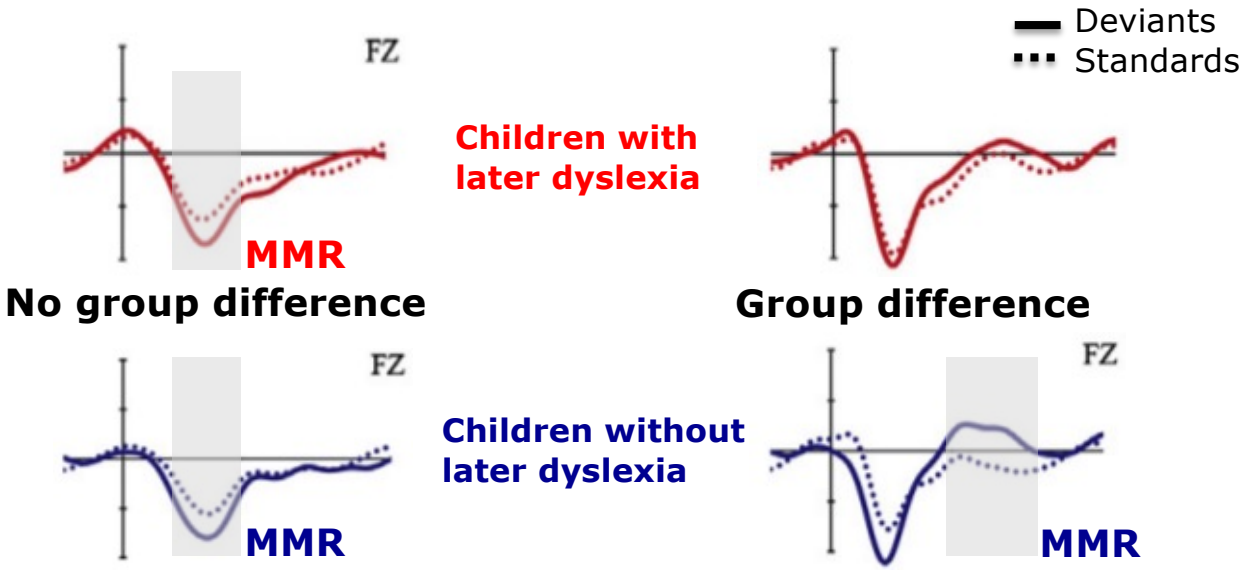

Infants with later dyslexia show reduced phoneme discrimination already during infancy (when phoneme representations become native language-specific)

Schaadt, Männel et al., 2015, Res Dev Disabil

Phonological processing as predictor of language learning

Healthy populations

- Development of phoneme perception (specifically consonant perception) during infants' first year of life statistically predicts children's receptive vocabulary at 12 months
- Early phoneme perception might be altered due to *less optimal learning conditions* (postpartum maternal mood)

Clinical populations

- Deficient phoneme perception observed already during infancy for children with later *developmental dyslexia* (emerges in an interaction of predisposition and native-language experience)

Thank you for your attention!

Research group *Early language acquisition*






External PhD students




Funding

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