



Infant research with EEG and OPMs

Beauty and the beast of developmental electrophysiology

Marlene Meyer

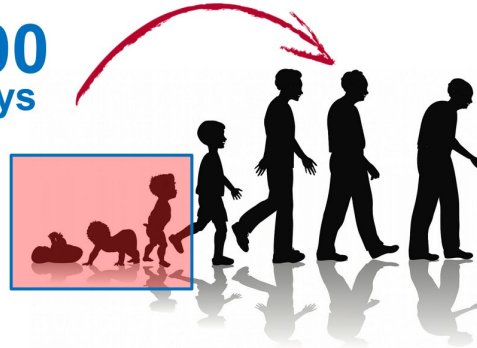
Infant research with EEG and OPMs

Understanding early development

Cognitive, motor, and social skills develop at a breath-taking rate in early development.



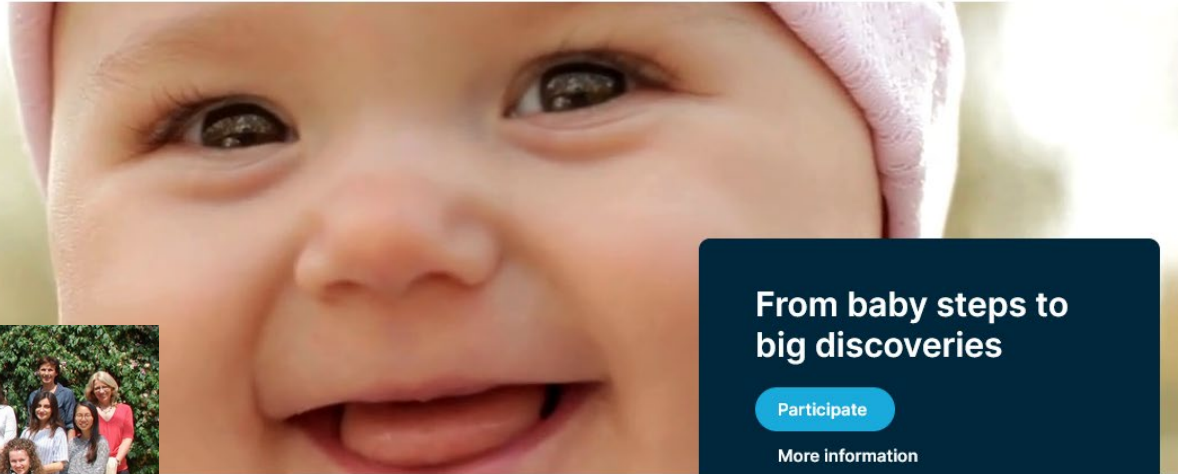
First
1000
days



Infant research with EEG and OPMs

Understanding early development

Baby
BRAIN



**From baby steps to
big discoveries**

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My research

Which cognitive processes and neural underpinnings play a role in:

Learning
from others



Thinking
about others

Interacting
with others

Infant research with EEG and OPMs

Understanding early development

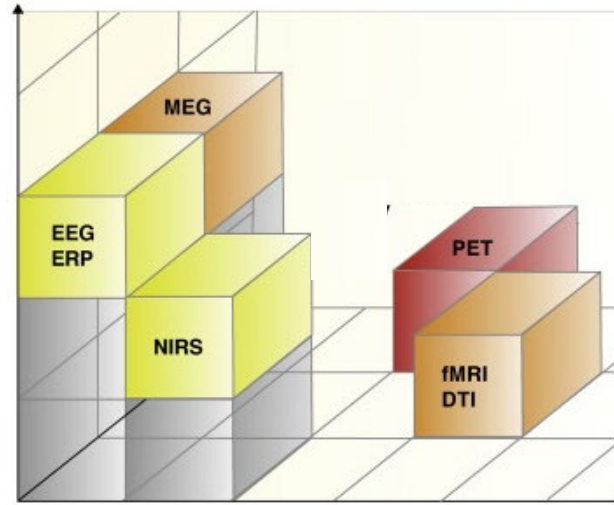
Cognitive, motor, and social skills develop at a breath-taking rate in early development.

Understanding the neural underpinnings that drive these developmental changes is crucial to advance our knowledge on early development.



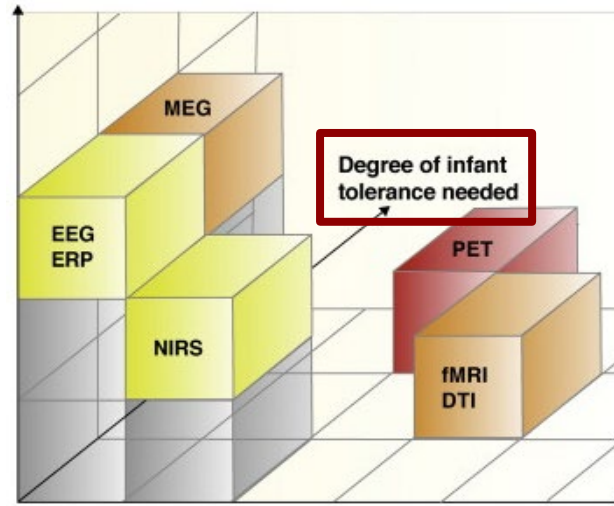
Infant research with EEG and OPMs

Neuroscience with babies



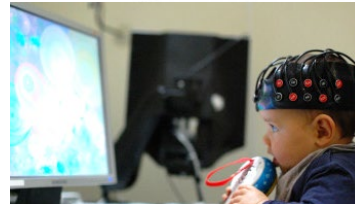
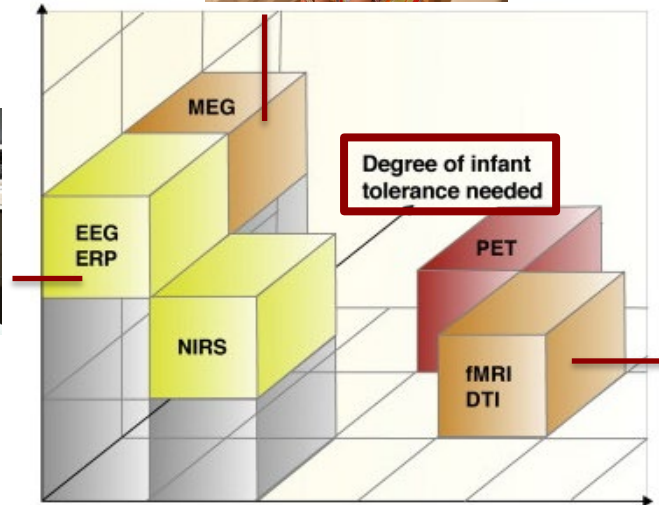
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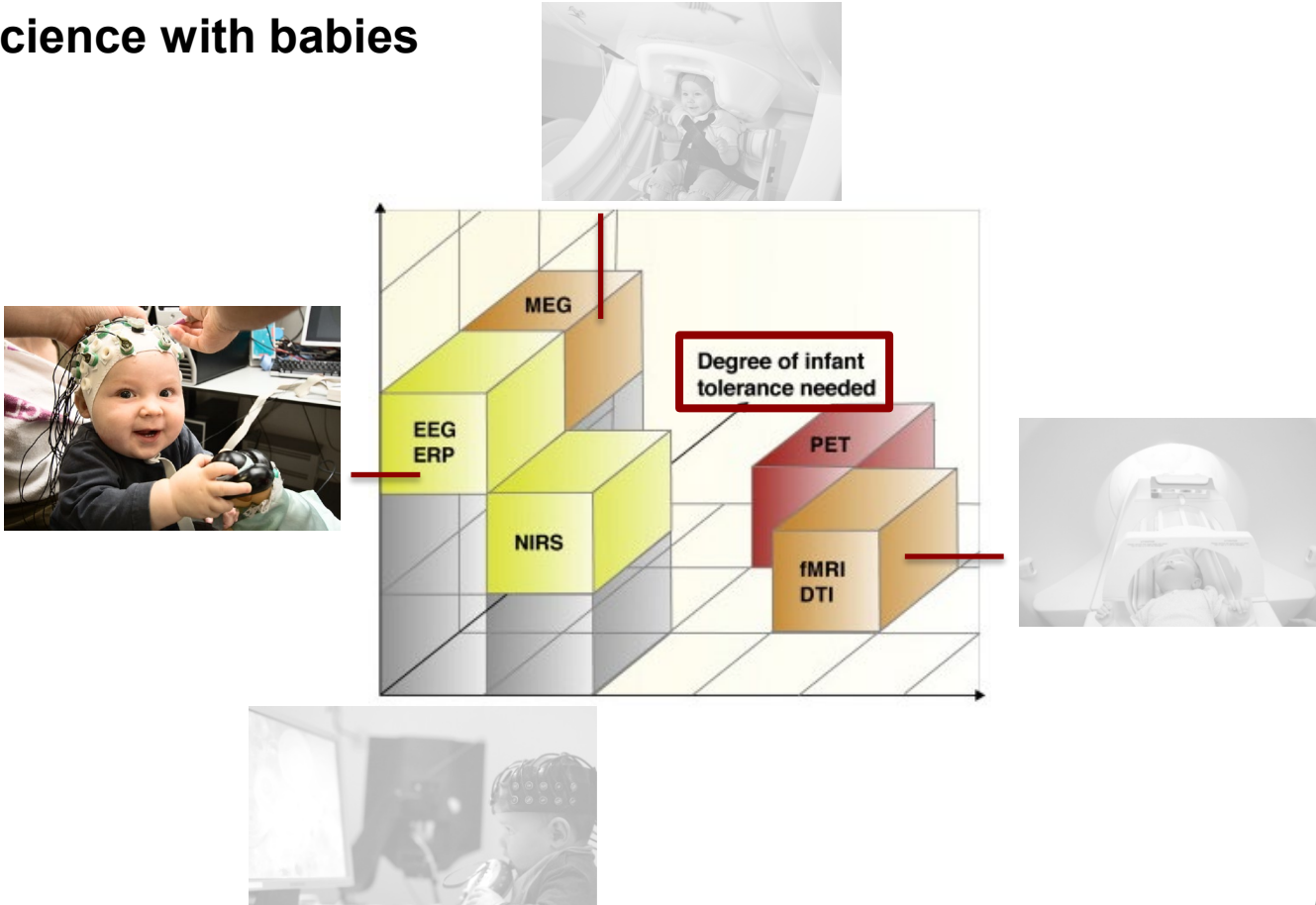
Infant research with EEG and OPMs

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Neuroscience with babies



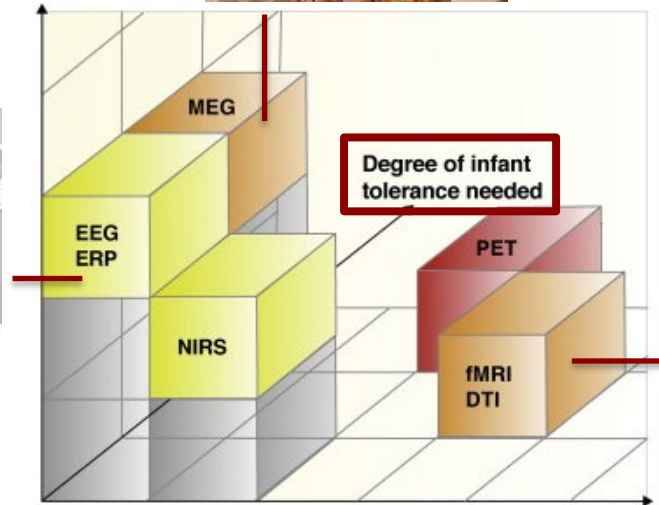
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Neuroscience with babies



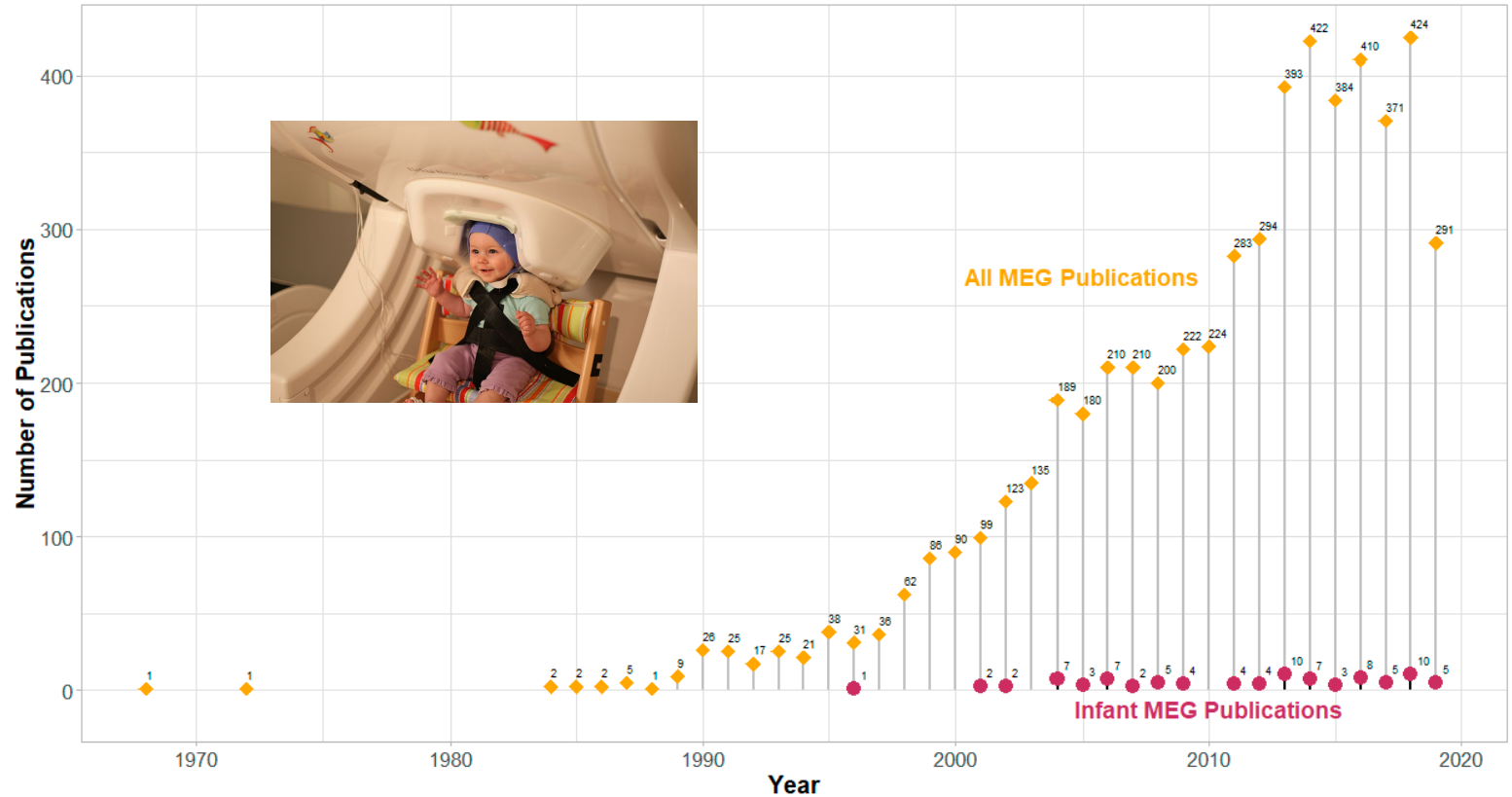
Infant research with EEG and OPMs

SQUID-based MEG



Infant research with EEG and OPMs

SQUID-based MEG





Infant research with EEG and OPMs

Challenges with SQUID-based MEG

- SQUID-MEG requires cryogenic cooling and is therefore very **costly** and typically **only available with adult-sized helmets**
- Only a handful labs in the world own child-/infant-sized SQUID-MEG systems

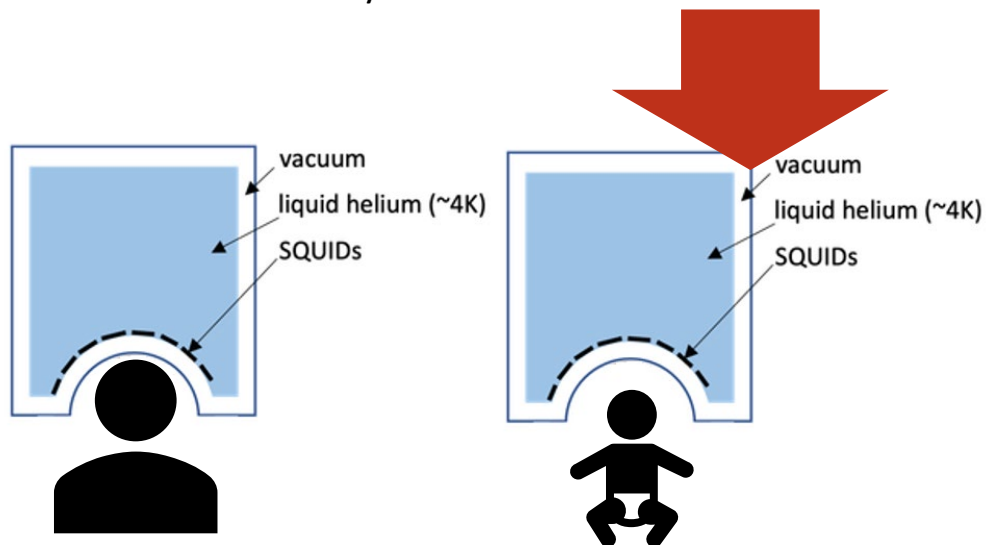


Figure adapted from natmeg.se

- infants' smaller head sizes lengthens the distance between their brains and the MEG sensors in adult MEG helmets
- leads to **weaker magnetic signals** being measured, and the spatial resolution can be severely compromised due to the **lower signal-to-noise ratios**

Figure adapted from natmeg.se; Kao & Zhang, 2029



Infant research with EEG and OPMs

Challenges with SQUID-based MEG

- SQUID-MEG requires cryogenic cooling and is therefore very **costly** and typically **only available with adult-sized helmets**
- Only a handful labs in the world own child-/infant-sized SQUID-MEG systems



→ **Inhomogeneity:** signal recorded at the side closest to the MEG helmet would be the strongest, and the weaker signals would be measured at the opposite side further away from the helmet

Kao & Zhang, 2029

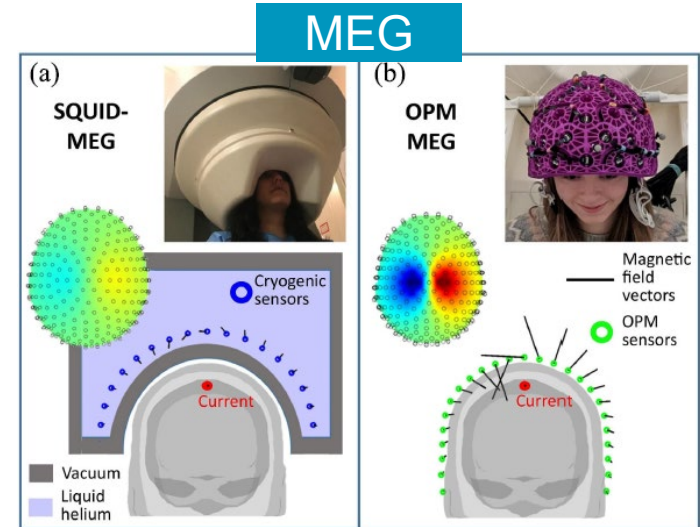
Figure from UT Southwestern

Infant research with EEG and OPMs

OPM-MEG with babies

Advent of **optically-pumped magnetometers (OPMs)**

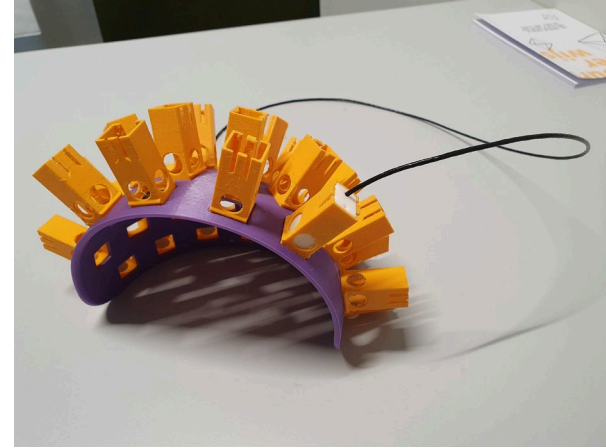
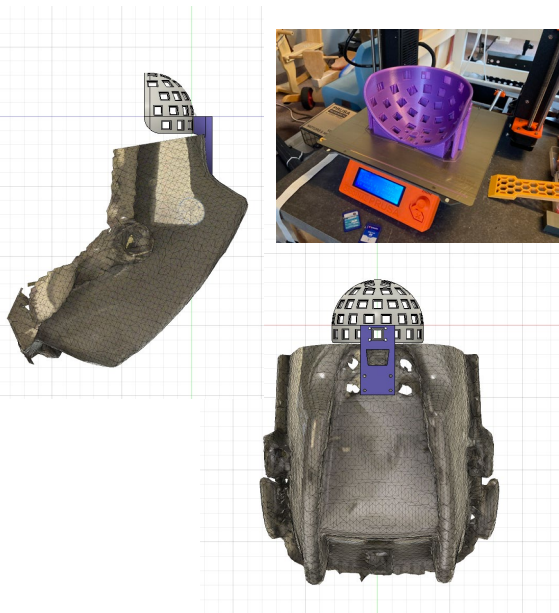
- alternative to cryogenic MEG
- opened new avenues for infant MEG research
- sensors do not require cooling and can be placed flexibly close to the head



Infant research with EEG and OPMs

OPM-MEG with babies

Development of a novel set-up that allows measuring brain of infants
We designed 3D-printed OPM headrests tailored to different head sizes



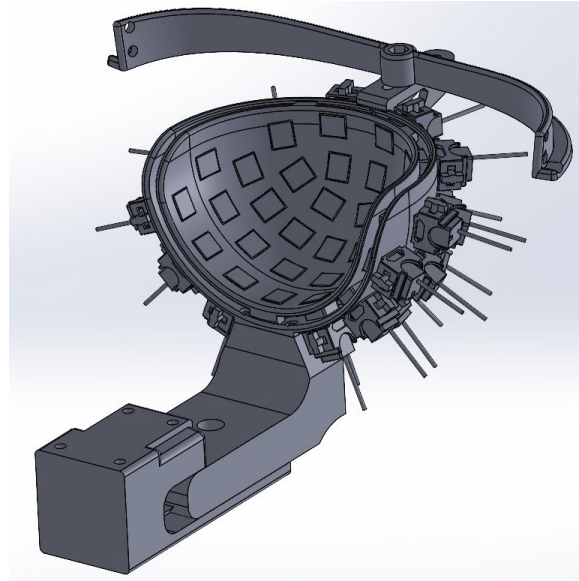
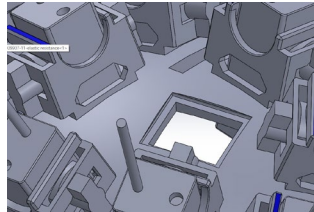
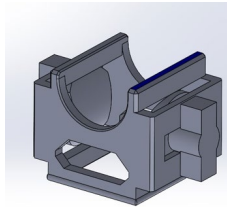
Infant research with EEG and OPMs

OPM-MEG with babies



Development of a novel set-up that allows measuring brain of infants
We designed 3D-printed OPM headrests tailored to different head sizes

32 OPM sensors distributed over occipital, parietal, temporal and central areas



Infant research with EEG and OPMs

OPM-MEG set-up to measure infant brain activity

Proof-of-principle study with 4- to 6-month-old infants ($N = 50$)

GOAL

Developing a novel set-up that allows measuring brain activity of infants using OPM-MEG

RESEARCH QUESTION

Can we replicate previous electrophysiological findings of visual and auditory processing in infants using our novel OPM-MEG setup?



Infant research with EEG and OPMs

OPM-MEG set-up to measure infant brain activity



Testing 4- to 6-month-old babies

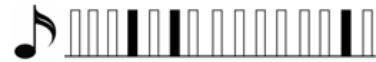
Infant research with EEG and OPMs

OPM-MEG set-up to measure infant brain activity



STIMULI

- 2 audio-visual stimulus sets (7min each)
- to replicate previous electrophysiological findings



1) in infants:

- faces vs. houses
- standard vs. oddball

2) in adults:

- oscillatory changes to luminance
- auditory steady state responses to rhythmic stimuli

Infant research with EEG and OPMs

OPM-MEG set-up to measure infant brain activity



— PRELIMINARY RESULTS —

Faces vs. Houses

- Average number of trials: 67.2 (faces), 66.4 (houses)

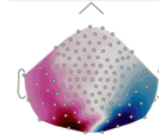
PREVIOUS FINDINGS

Topography

Faces (~300 ms)

7-month-old infant

Cryogenic MEG



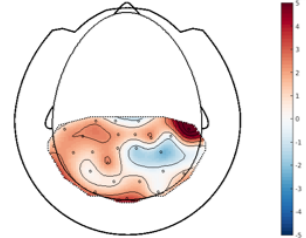
from Chen and colleagues³

Topography

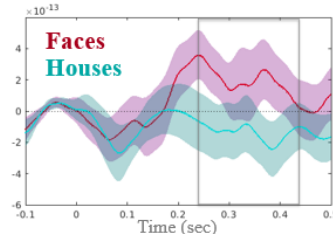
Faces (250 ms–450 ms)

Time-course

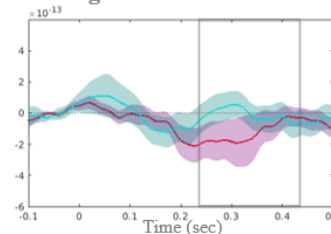
Consistent with Chen and colleagues³ who observed stronger Face vs. Non-Face responses between 250–450 ms



Left Parietal Sensors



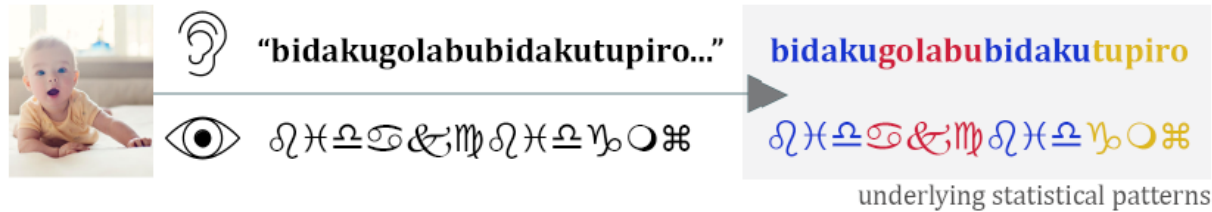
Right Parietal Sensors



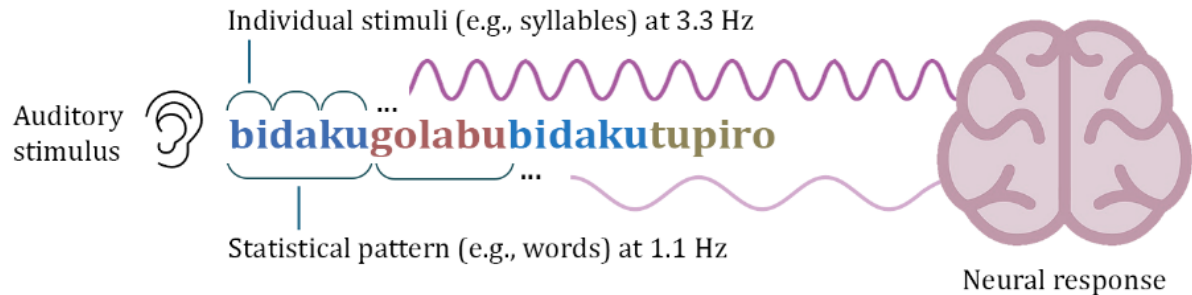
Infant research with EEG and OPMs

Additional research questions addressed with OPM-MEG paradigms

Research Question: How do visual and auditory statistical learning develop in infancy? (Ailan Kalledat)



Paradigm: Frequency Tagging



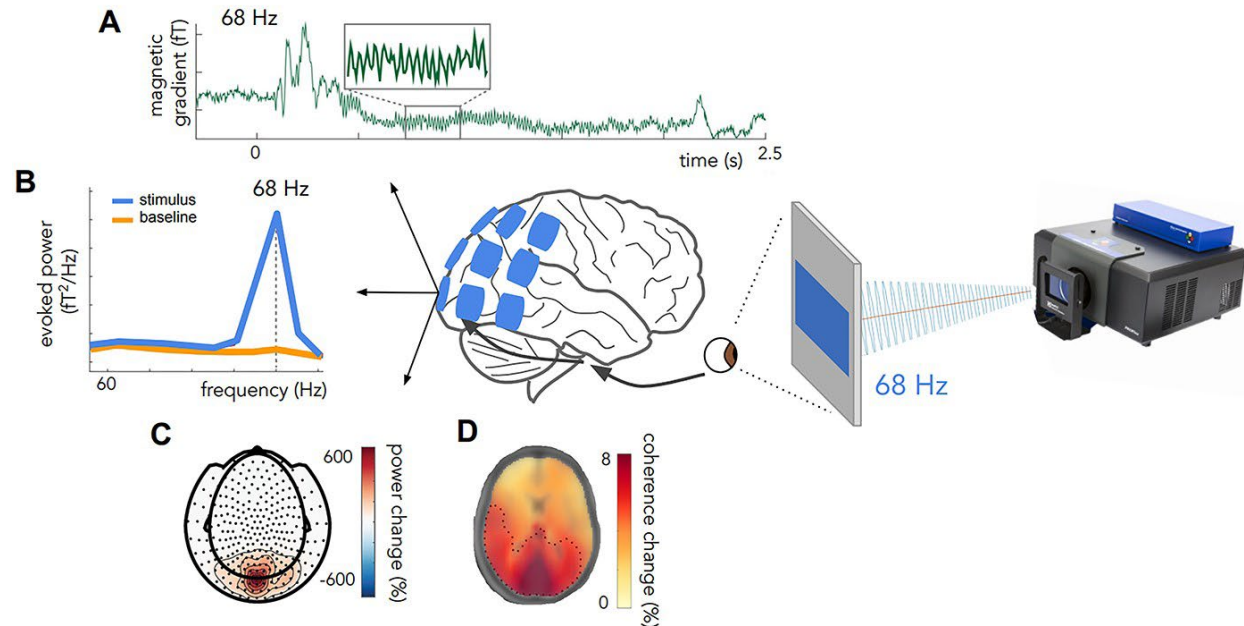
Adapted from Siegelman et al., 2018; brain icon from Vojtěch Hřeček according to CC BY-SA 4.0

Infant research with EEG and OPMs

Additional research questions addressed with OPM-MEG paradigms

Research Question: Does Rapid Invisible Frequency Tagging (RIFT) reliably elicit a neural response in infants? (Jelmer Luijt)

Paradigm: RIFT



Infant research with EEG and OPMs

Differences compared with studies on adults



Infant research with EEG and OPMs

Differences compared with studies on adults

Adults

typically instructed not to move and to reduce eye-movements to a minimum

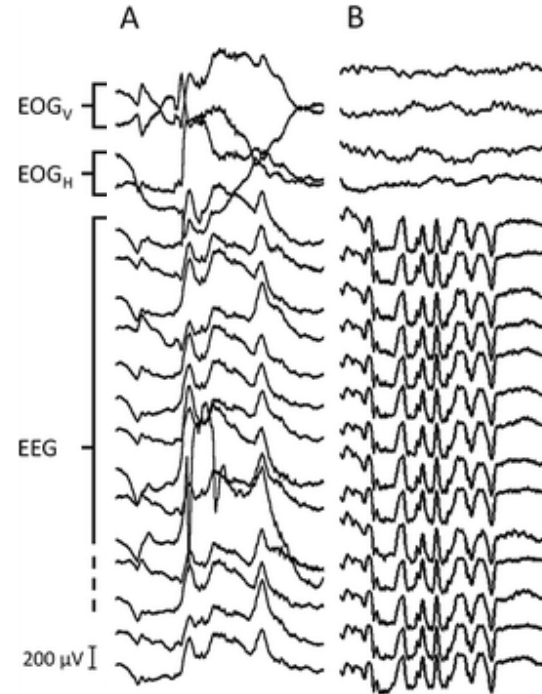
Infants

cannot be instructed so that (large) movements during infant EEG recordings are unavoidable



Infant research with EEG and OPMs

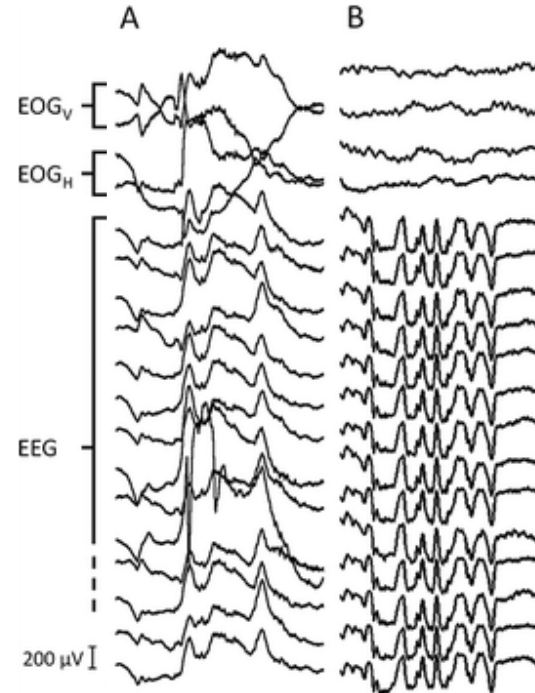
Movements and their artifacts in infant EEG



Movements and their artifacts in infant EEG

Typical examples

- Kicking with their feet
- Turning (to caregiver)
- Crying
- Laughing
- Sucking on pacifier or hand
- Pointing
- Pooping



Infant research with EEG and OPMs

Movements and infant M/EEG research

How to measure movements in infants?



©2022 Kanazawa et al

Infant research with EEG and OPMs

Movements and infant M/EEG research

Measuring movements

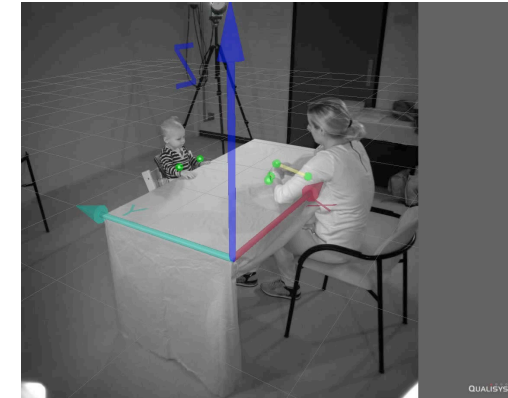
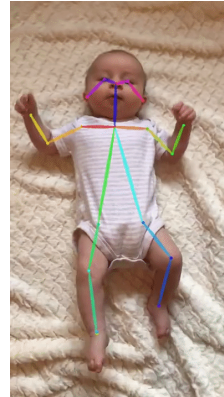
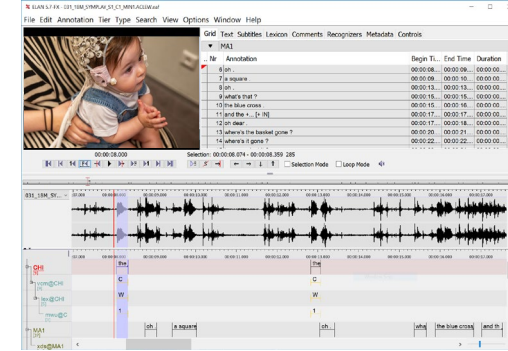
- Manually coding movements from video
- Marker-based motion-tracking
- Markerless motion-tracking
- Inertial motion-tracking

Infant research with EEG and OPMs

Movements and infant M/EEG research

Measuring movements

- Manually coding movements from video
- Marker-based motion-tracking
- Markerless motion-tracking
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Infant research with EEG and OPMs

Movements and infant M/EEG research

Movements



Artifact in the signal

Signal of interest

Infant research with EEG and OPMs

Movements and infant M/EEG research

Movements



Artifact in the signal

- Reduce movements
- Exclude movements

Signal of interest

- Use movements

Infant research with EEG and OPMs

Movements and infant M/EEG research

Movements



Artifact in the signal

- Reduce movements
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Signal of interest

- Use movements

Infant research with EEG and OPMs

Reducing movement artifacts during data acquisition



Design choices to reduce movements

- Seating infants in an infant car seat
- Tilting the screen so that infants can lean back
- Folding infants in a blanket ("baby burrito")



Infant research with EEG and OPMs

Excluding movement artifacts during data processing

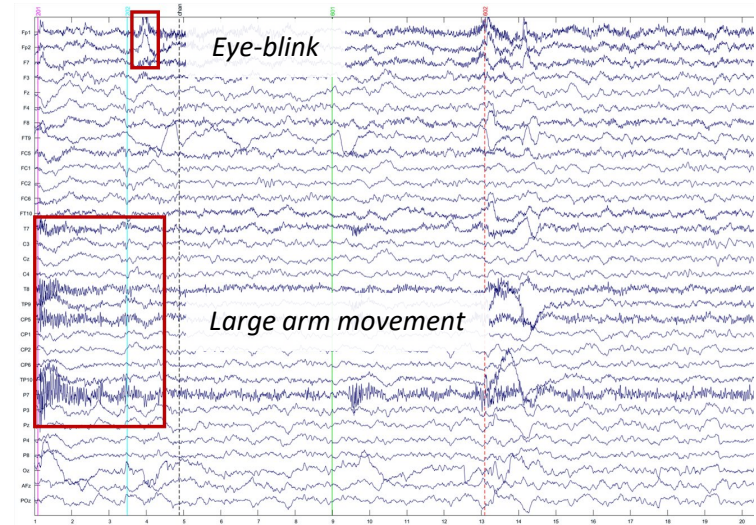
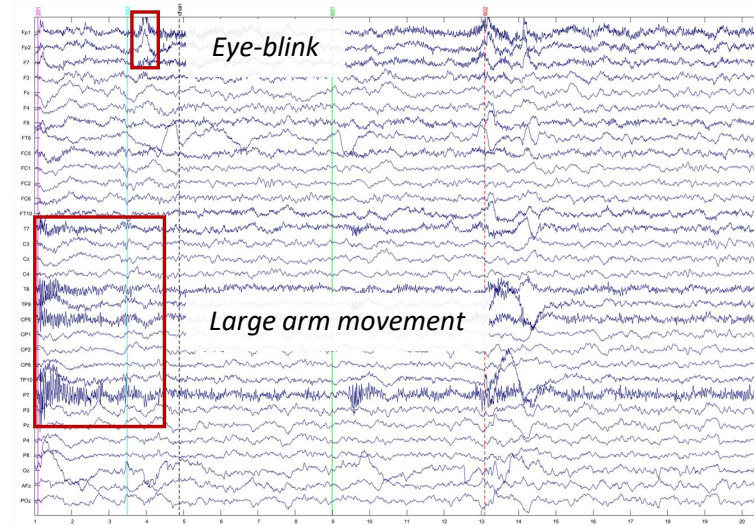


Figure from Georgieva et al., (2020). *Frontiers in Neuroscience*

Excluding movement artifacts during data processing

Examples of dealing with movement artifacts in developmental studies

- Excluding noisy data during EEG artifact rejection based on (amplitude) thresholds



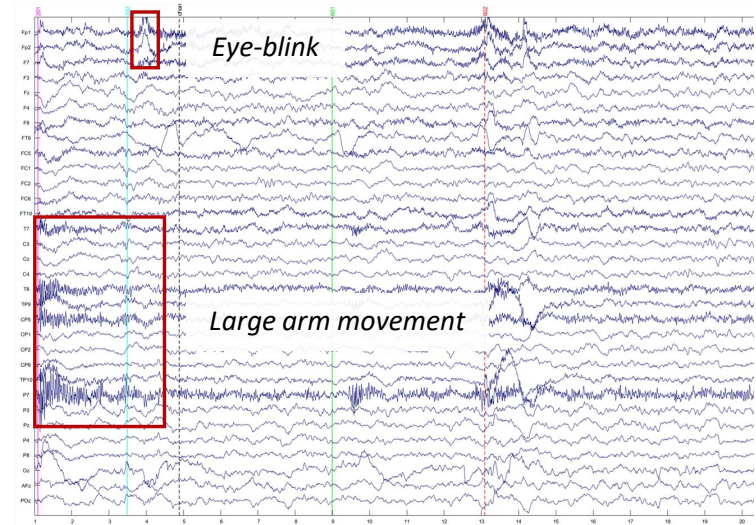
Infant research with EEG and OPMs

Excluding movement artifacts during data processing

Examples of dealing with movement artifacts in developmental studies

- Excluding noisy data during EEG artifact rejection based on (amplitude) thresholds

- Captures large movements but potentially not smaller ones
- Agnostic about movements
- Determining standardized threshold in infant EEG remains difficult
- Potentially high data loss



Excluding movement artifacts during data processing

Examples of dealing with movement artifacts in developmental studies

- Using automatic correction approaches, like ICA, Artifact Blocking etc. to correct rather than reject data
 - Might fail for less stereotypical artifacts as observed in infants (Georgieva et al., 2020)
 - Correction might still remove meaningful neural data or distort the signal

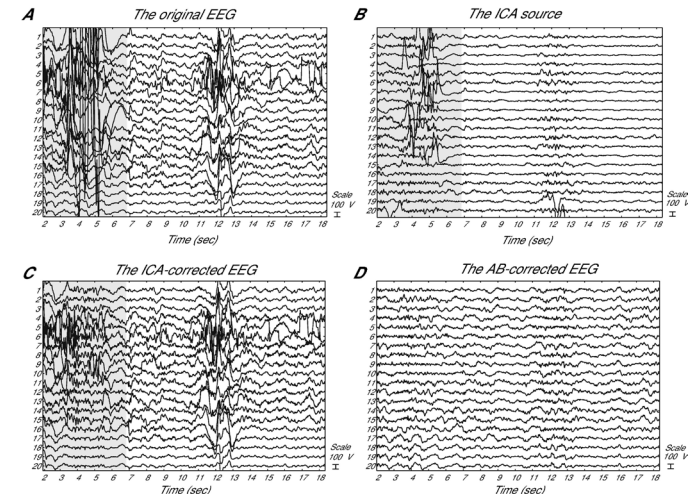
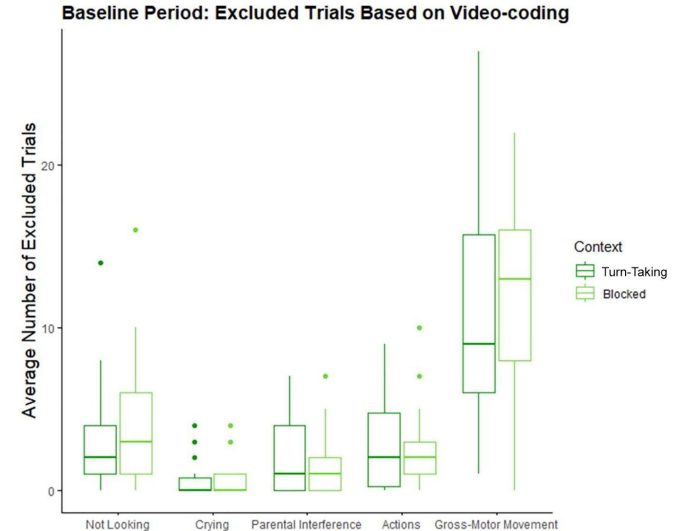
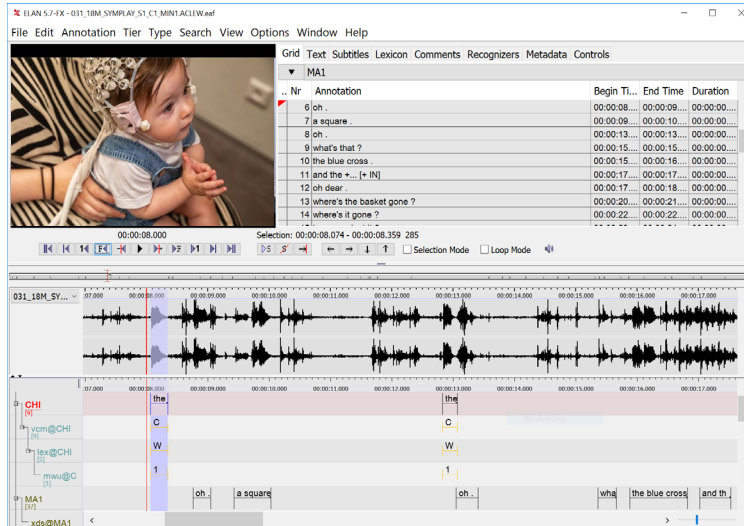


Figure from Fujioka et al., (2011)

Measuring movements – manual video coding

Examples of dealing with movement artifacts in developmental studies

- Excluding video-coded movements before further preprocessing steps^{1,2}



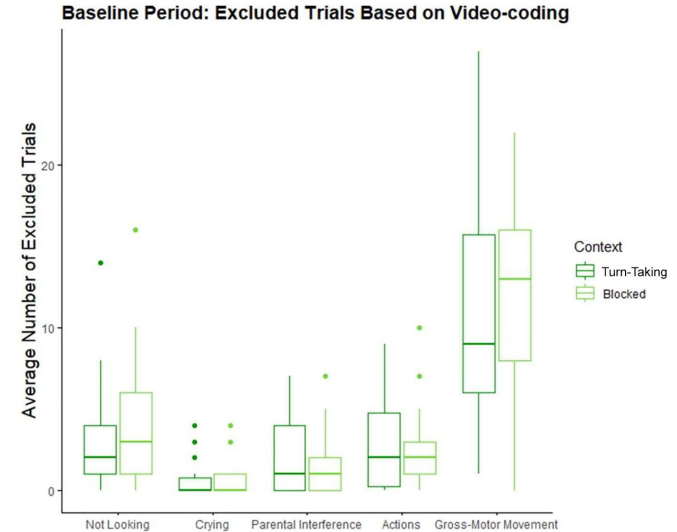
Infant research with EEG and OPMs

Measuring movements – manual video coding

Examples of dealing with movement artifacts in developmental studies

- Excluding video-coded movements before further preprocessing steps^{1,2}

- Video-coding is resource-heavy
- Movement exclusion is dependent on video-coding scheme and its reliability
- Considerable data loss



Measuring movements – manual video coding

Examples of dealing with movement artifacts in developmental studies

- Excluding video-coded movements before further preprocessing steps^{1,2}
 - Video-coding is resource-heavy
 - Movement exclusion is dependent on video-coding scheme and its reliability
 - Considerable data loss → some studies tested for condition-differences in the amount of movement and, if no difference was present, left movements in the data

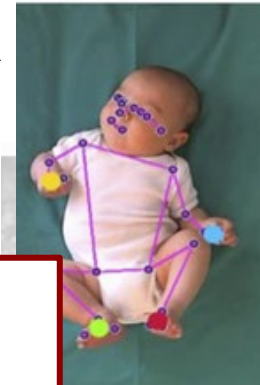
Infant research with EEG and OPMs

Excluding movements during data processing



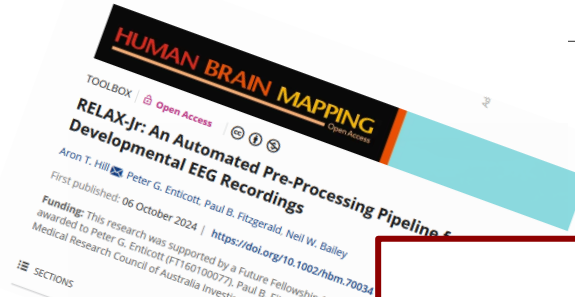
Infant research with EEG and OPMs

Excluding movements during data processing



Stay tuned!

**Ongoing research keeps developing improved
movement artifact methods for infant
electrophysiological data**



Developmental Cognitive Neuroscience

Volume 54, April 2022, 101068



NEAR: An artifact removal pipeline for human newborn EEG data

Automatic classification of ICA components from infant EEG using MARA

I. Marriott Horesign ^a, E. Phillips ^a, M. Whitehorn ^a, V. Noreika ^b, E.J.H. Jones ^c, V. Leong ^d, S.V. Wess ^e

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<https://doi.org/10.1016/j.dcn.2021.101024>

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Adjusting ADJUST: Optimizing pediatric data using geodesic nets

Stephanie C. Leach, Santiago Morales, Maureen E. Bowers, George A. Buzzell, Ranjan Debnath, Daniel Beall, Nathan A. Fox

First published: 17 March 2020 | <https://doi.org/10.1111/psyp.13566> | Citations: 69

Funding information

This work was supported by the National Institutes of Health (P01HD064653 and U01MH093349 to NAF and UH3 OD023279 to Amy J. Elliott).

PDF TOOLS SHARE

SECTIONS

Infant research with EEG and OPMs

Movements and infant M/EEG research

Movements



Artifact in the signal

- Reduce movements
- Exclude movements

Signal of interest

- Use movements

Infant research with EEG and OPMs

Using movements as focus of interest

Topics of research that focus on movements in infant EEG

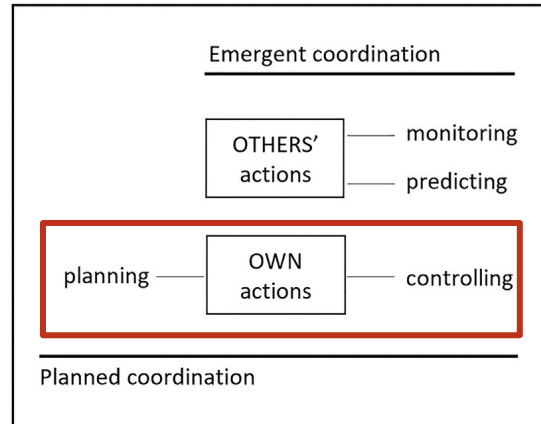
- Studying the sense of agency
- Better understanding the neural underpinnings of motor development
- The role of movements in action perception research

Infant research with EEG and OPMs

Using movements as focus of interest

Topics of research that focus on movements in infant EEG

- Studying the sense of agency
- **Better understanding the neural underpinnings of motor development**
- The role of movements in action perception research



Infant research with EEG and OPMs

Better understanding the neural underpinnings of motor development

Neural response related to a simple grasping movement in 9-month-olds



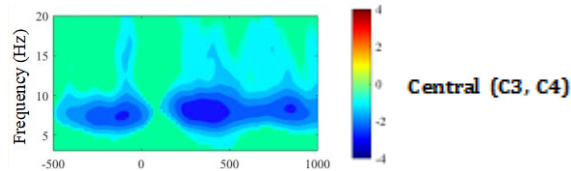
Infant research with EEG and OPMs

Better understanding the neural underpinnings of motor development

Neural response related to a simple grasping movement in 9-month-olds

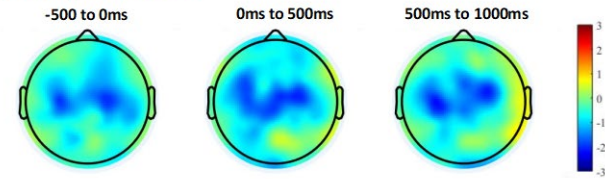
A. Time-frequency plot

(a) Grasp Condition



B. Topographic maps of mu (6-9Hz) band

(a) Grasp Condition



Infant research with EEG and OPMs

Better understanding the neural underpinnings of motor development

Neural response related to a simple grasping movement and novel tool-use movements in 9-month-olds

(a) Grasp Condition



(b) Cane-use Condition



Familiar and novel actions at 9 months

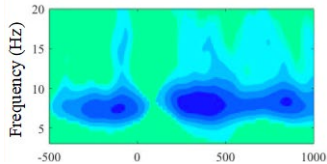
Infant research with EEG and OPMs

Better understanding the neural underpinnings of motor development

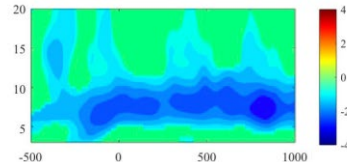
Neural response related to a simple grasping movement and novel tool-use movements in 9-month-olds

A. Time-frequency plot

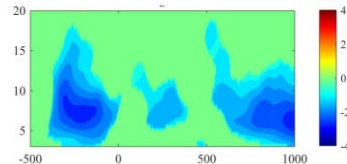
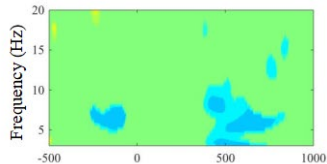
(a) Grasp Condition



(b) Cane-use Condition



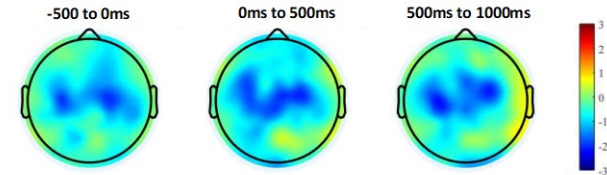
Central (C3, C4)



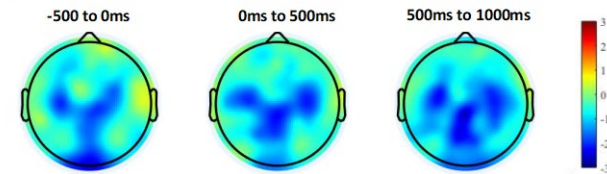
Occipital (O1, O2)

B. Topographic maps of mu (6-9Hz) band

(a) Grasp Condition



(b) Cane-use Condition



Novel action (cane-use) elicits mu suppression over central and occipital sites

Infant research with EEG and OPMs

Better understanding the neural underpinnings of motor development

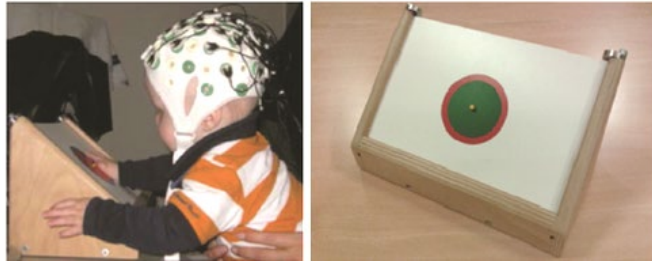
Changes in neural motor response to grasping with age



Infant research with EEG and OPMs

Better understanding the neural underpinnings of motor development

Changes in neural motor response to grasping with age



8-month-olds

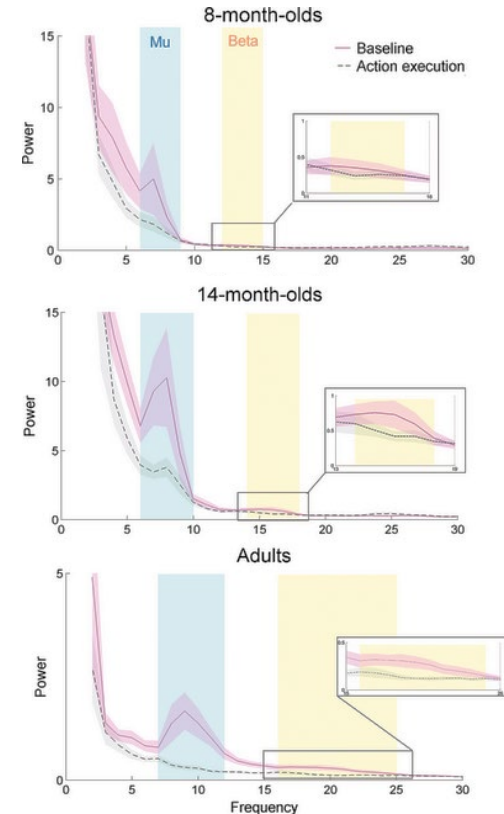
- show Mu but **not** Beta power suppression during execution

14-month-olds

- show Mu and Beta power suppression during execution

Overall

- Mu and Beta bands shift to higher frequencies with age

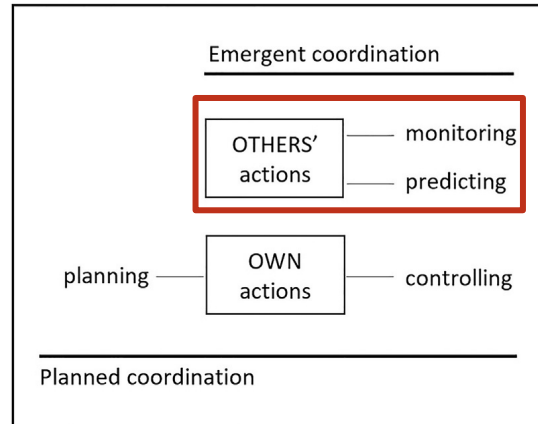


Infant research with EEG and OPMs

Using movements as focus of interest

Topics of research that focus on movements in infant EEG

- Studying the sense of agency
- Better understanding the neural underpinnings of motor development
- **The role of movements in action perception research**



Infant research with EEG and OPMs

The role of movements in action perception research

Neural Mirroring: Similar brain activation during **action execution** & **observation**

[Rizzolatti & Craighero, 2004; Marshall & Meltzoff, 2011; Vanderwert, Fox & Ferrari, 2012]



Infant research with EEG and OPMs

The role of movements in action perception research

EEG study with infants

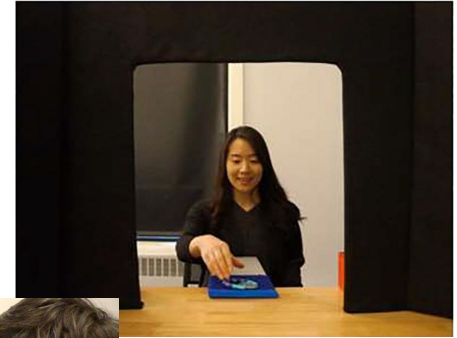
Participants:

- 9-month-olds (range: 8- to 10-month-olds)

Procedure (live):

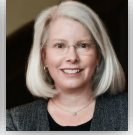
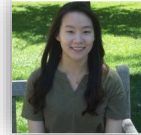
Within-subjects conditions

- Action observation, action execution
- 20 trials each

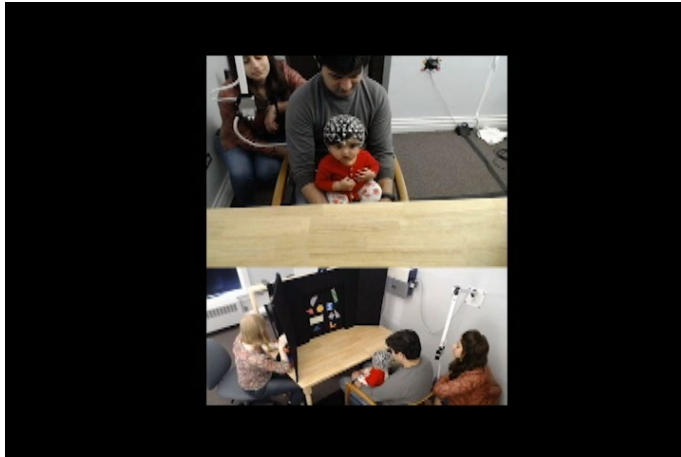


Infant research with EEG and OPMs

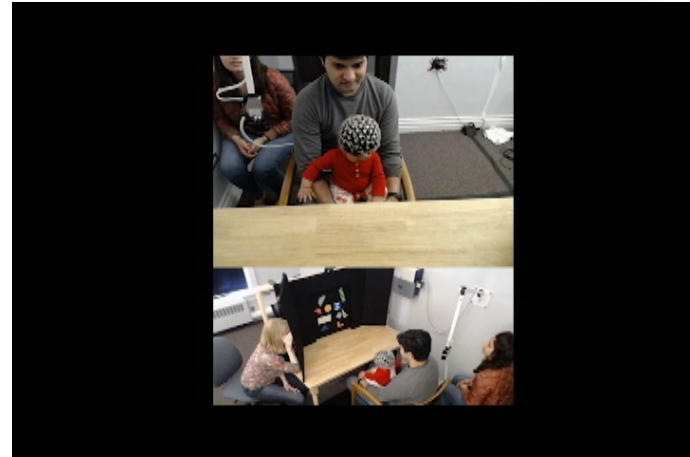
The role of movements in action perception research



Acting

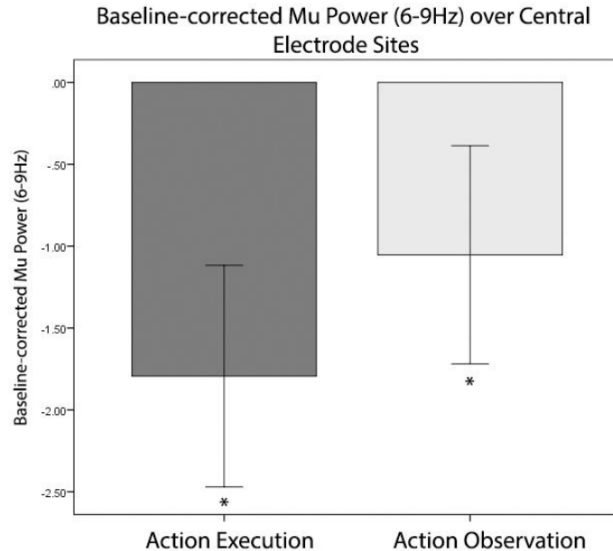


Observing



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9-month-old infants activate their neural motor system when they observe others' actions

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Does social context matter for neural processing of others' actions?

Passive observation



Observation during social interaction



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Neural motor activity is enhanced when...

- ...9-month-olds observe actions when engaged in turn-taking



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Neural motor activity is enhanced when...

- ...9-month-olds observe actions when engaged in turn-taking
- ...3-year-olds observe actions of a joint action partner
- ...4-year-olds observe an action with the intention to imitate it



Being actively engaged in a social interaction boosts young children's processing of others' actions.



The role of movements in action perception research

“something in the way you move”



Movement kinematics

- contain information about emotions and intentions of the actor
- vary in a communicative interaction dependent on the social partner

Infant research with EEG and OPMs

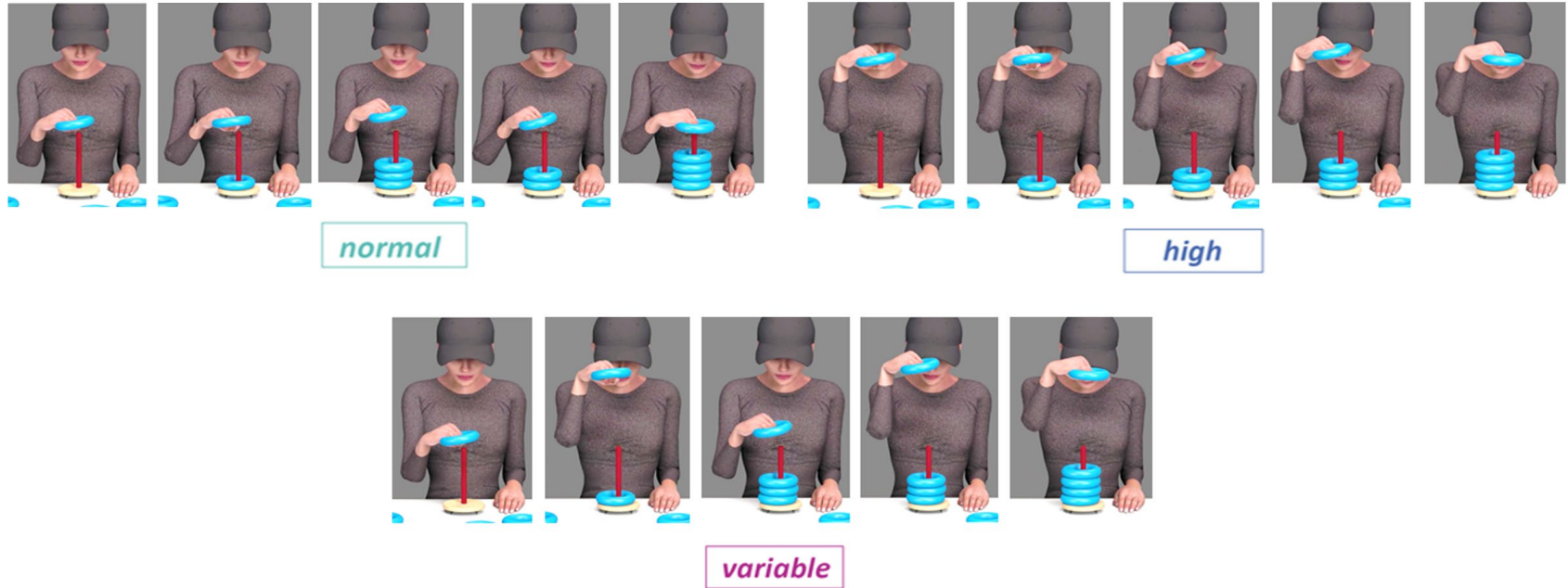
The role of movements in action perception research

How do movements draw infants' **attention** and facilitate their **learning**?

Infant research with EEG and OPMs

The role of movements in action perception research

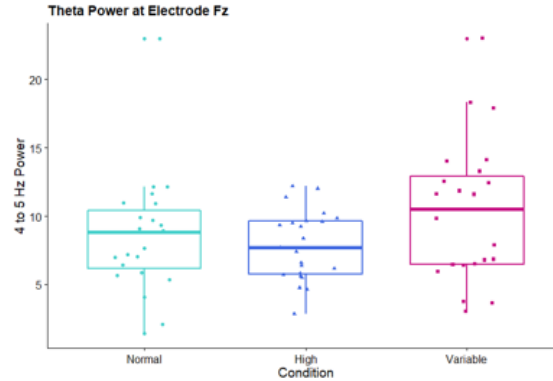
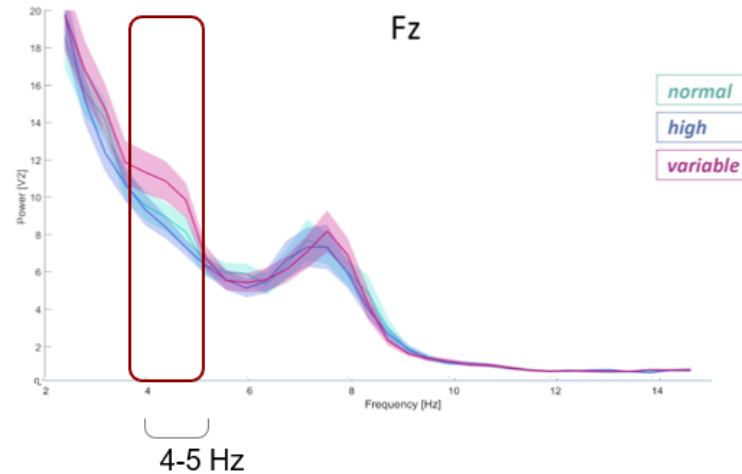
How do movements draw infants' **attention** and facilitate their **learning**?



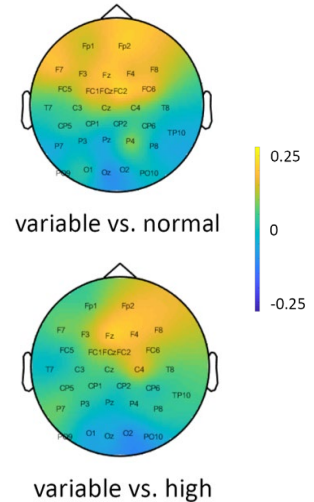
Infant research with EEG and OPMs

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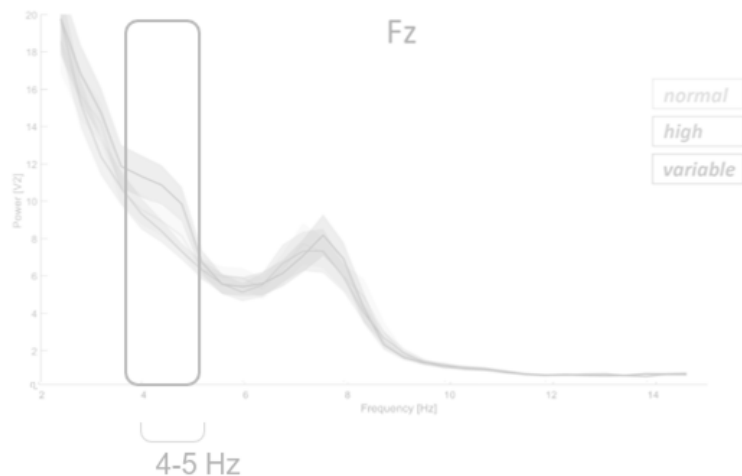
$F(2,44)=5.00, p=.01, \text{partial } \eta^2=.18$



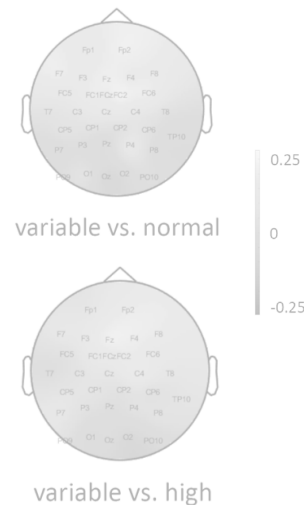
Infant research with EEG and OPMs

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How do movements draw infants' **attention** and facilitate their **learning**?



Children with **higher theta power** are more likely to **perform target action successfully**

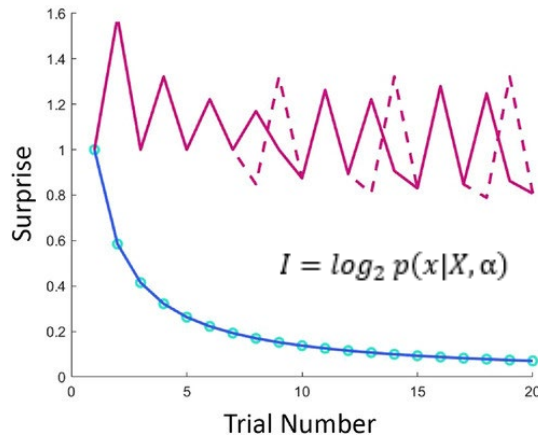


Variability in movements rather than larger movements enhances infants' frontal theta power, associated with attention in IDAs

Infant research with EEG and OPMs

The role of movements in action perception research

How do movements draw infants' **attention** and facilitate their **learning**?



Information theoretic **surprise** induced by movement variability
predicts infants' theta power

Infant research with EEG and OPMs

Using movements as focus of interest

Topics of research that focus on movements in infant EEG

- Studying the sense of agency
- Better understanding the neural underpinnings of motor development
- The role of movements in action perception research
- **...YOUR research!**



Thank you for your attention

Thanks to
all participating families and the **BabyBRAIN** research group



**Baby
BRAIN**



Questions?