DEVELOPING LOW COST WEARABLES TO TRACK EARLY HOME ENVIRONMENTS IN NEURODIVERGENT CHILDREN

Prof Sam Wass
s.v.wass@uel.ac.uk
twitter @profsamwass

UEL BABY DEV LAB

Environments influence children.
They influence each child differently.

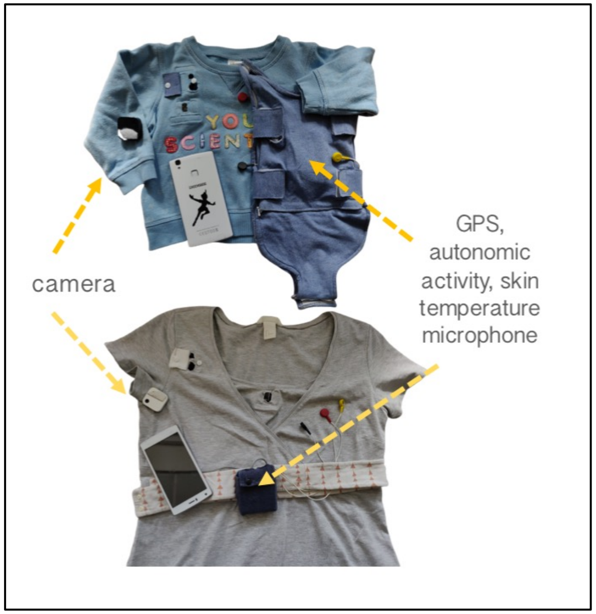
Environments influence children.
They influence each child differently.

Understanding how environments influence children is crucial to allow early home and educational environments for neurodivergent children

But our current methods for measuring how environments influence children are extremely limited.

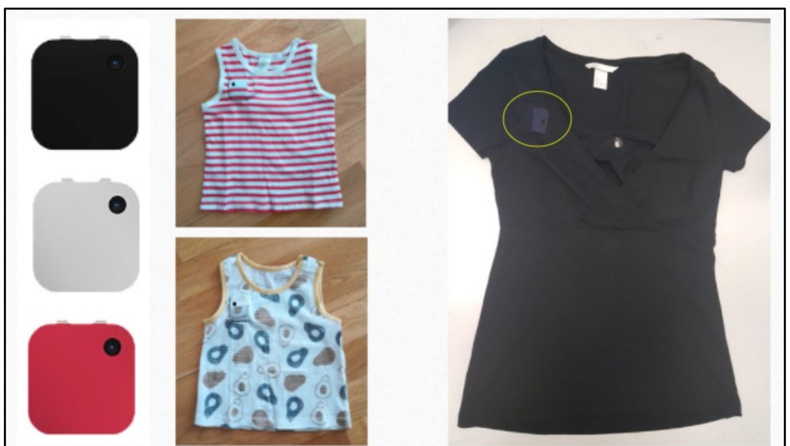
But our current methods for measuring how environments influence children are extremely limited.

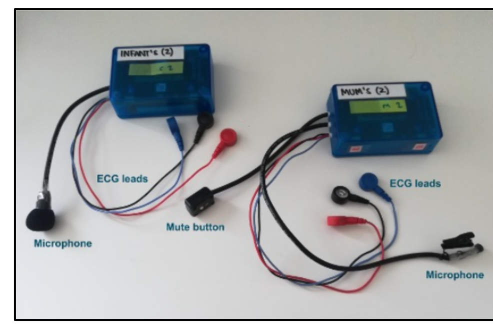
...questionnaires, lab-based observations...



Economic
and Social
Research Council

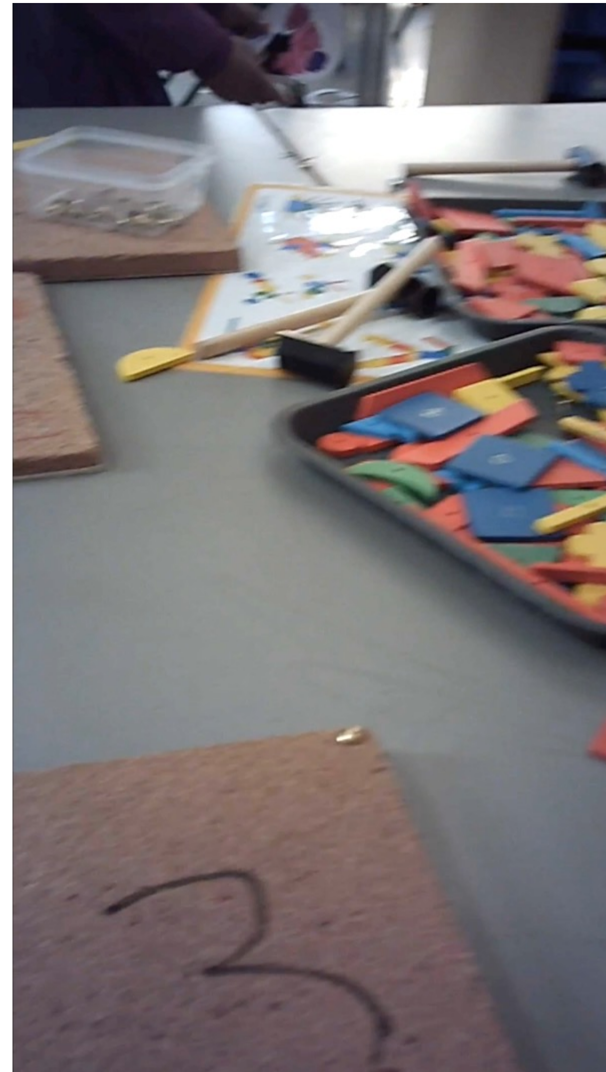
European Research Council
Established by the European Commission

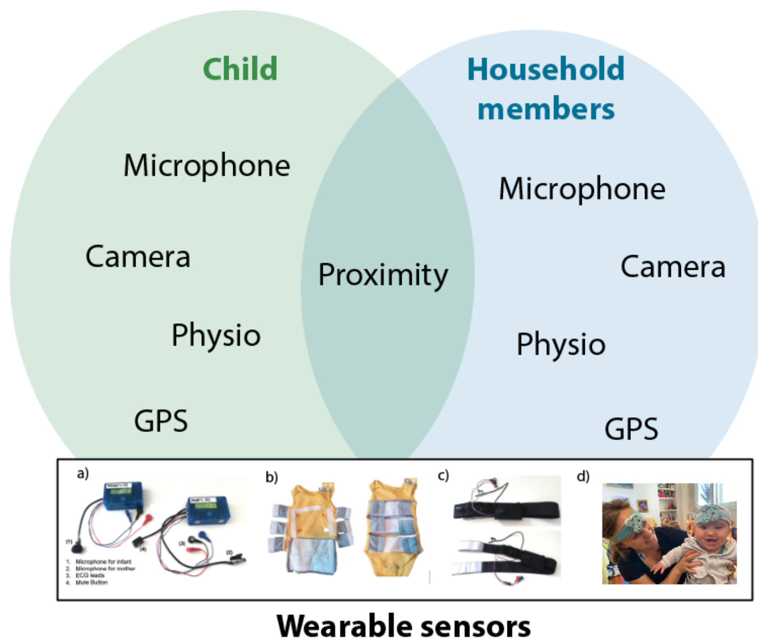




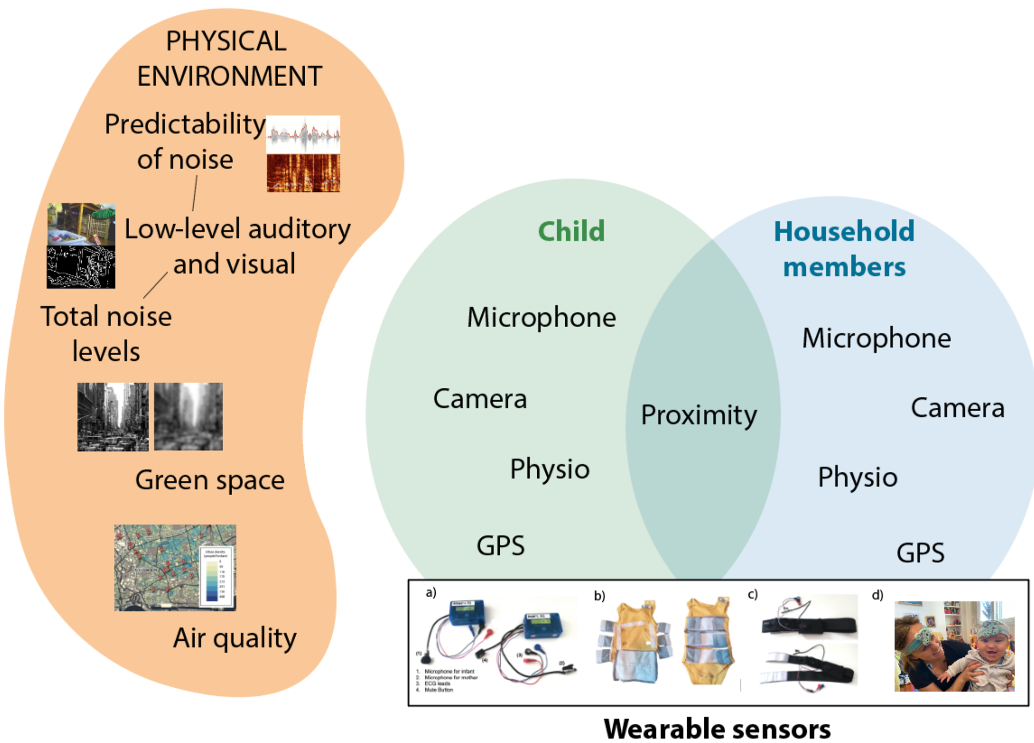

2022/05/09 08:36:01

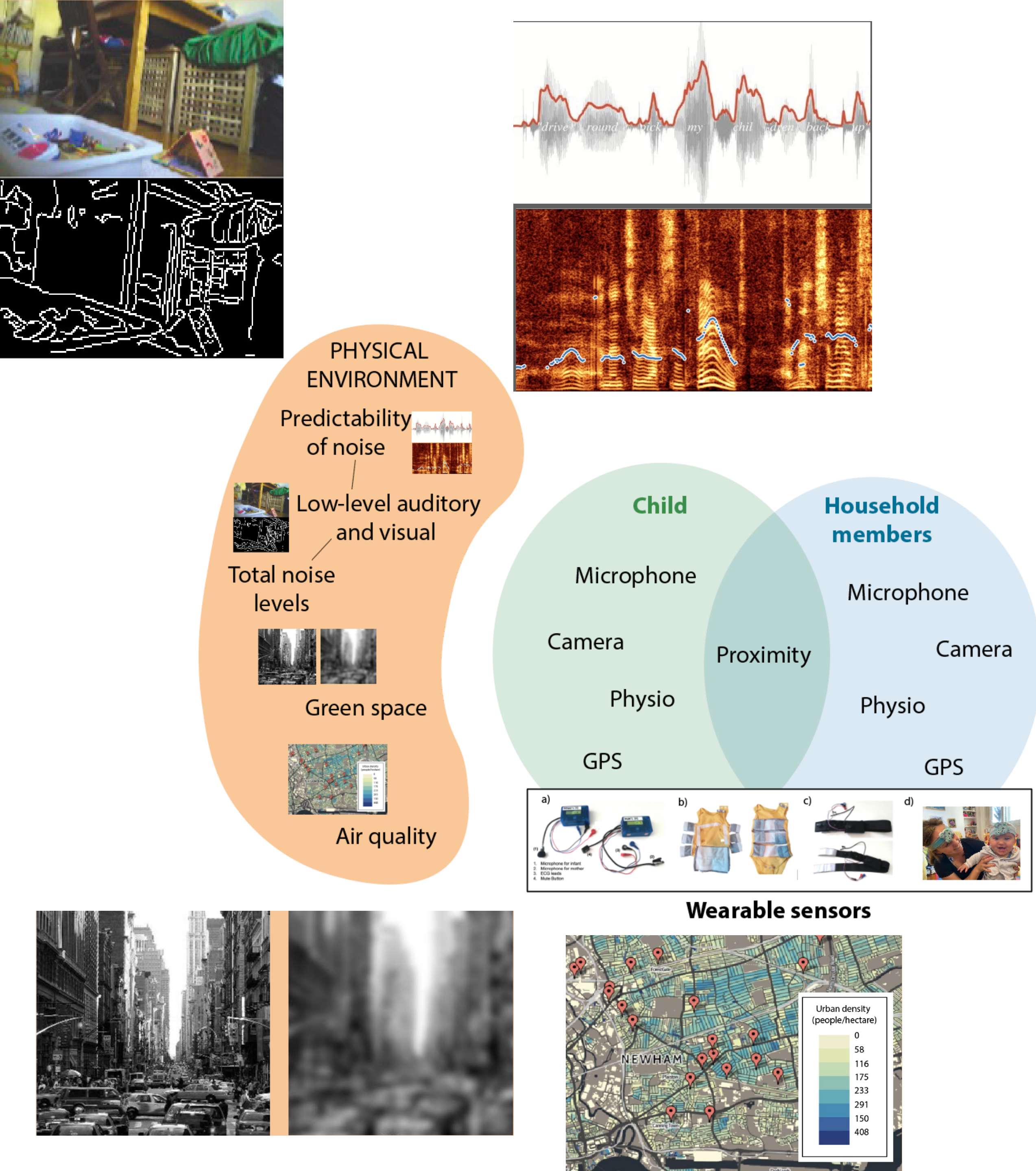

2022/05/09 08:39:56


3

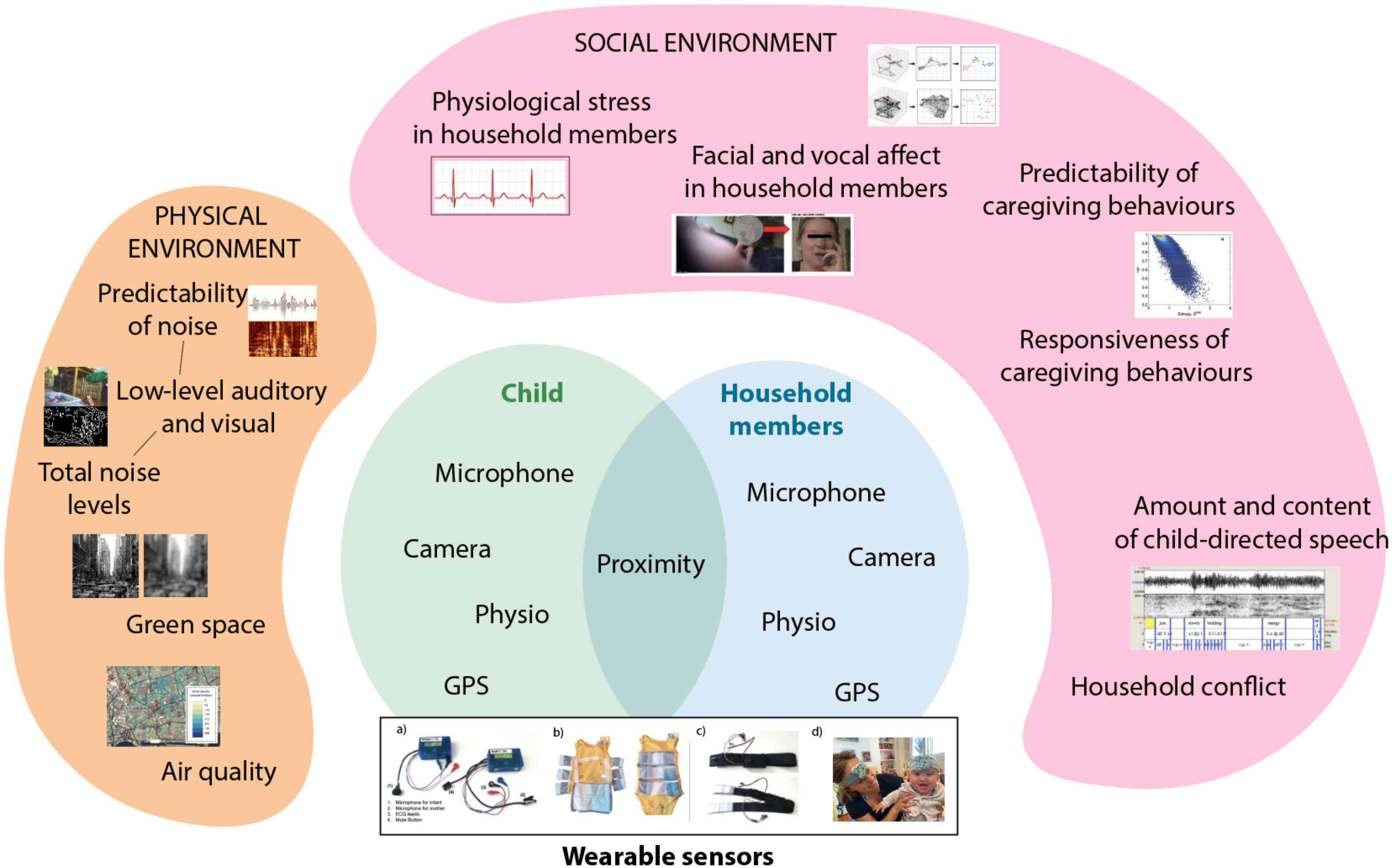


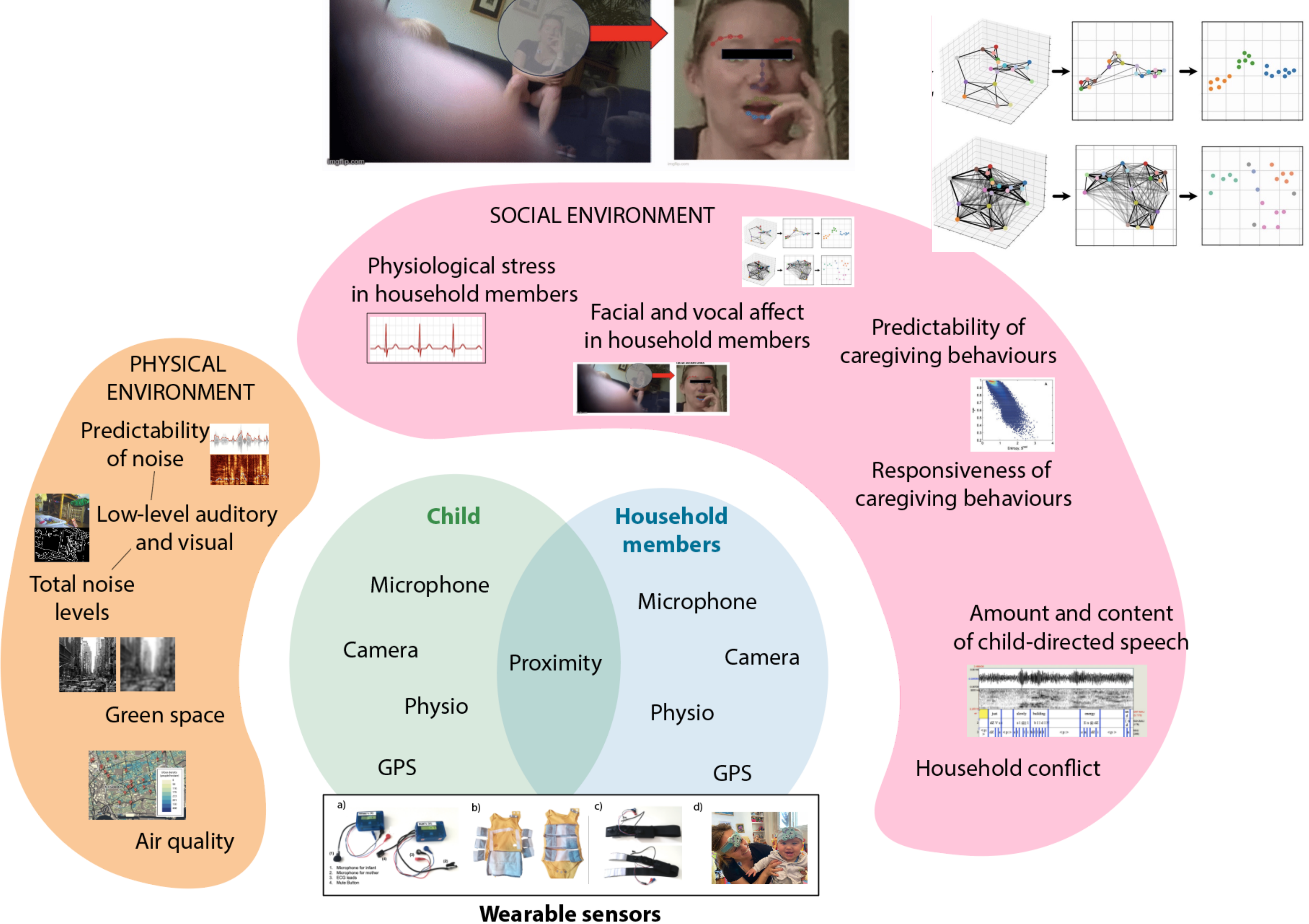
Child
Household members
Microphone
Camera
Physio
GPS
Proximity
Microphone
Camera
Physio
GPS
a)
b)
c)
d)
Wearable sensors


PHYSICAL ENVIRONMENT
Predictability of noise
Low-level auditory and visual
Total noise levels
Green space
Air quality
Child
Household members
Microphone
Camera
Physio
GPS
Proximity
Microphone
Camera
Physio
GPS
a)
b)
c)
d)
Wearable sensors

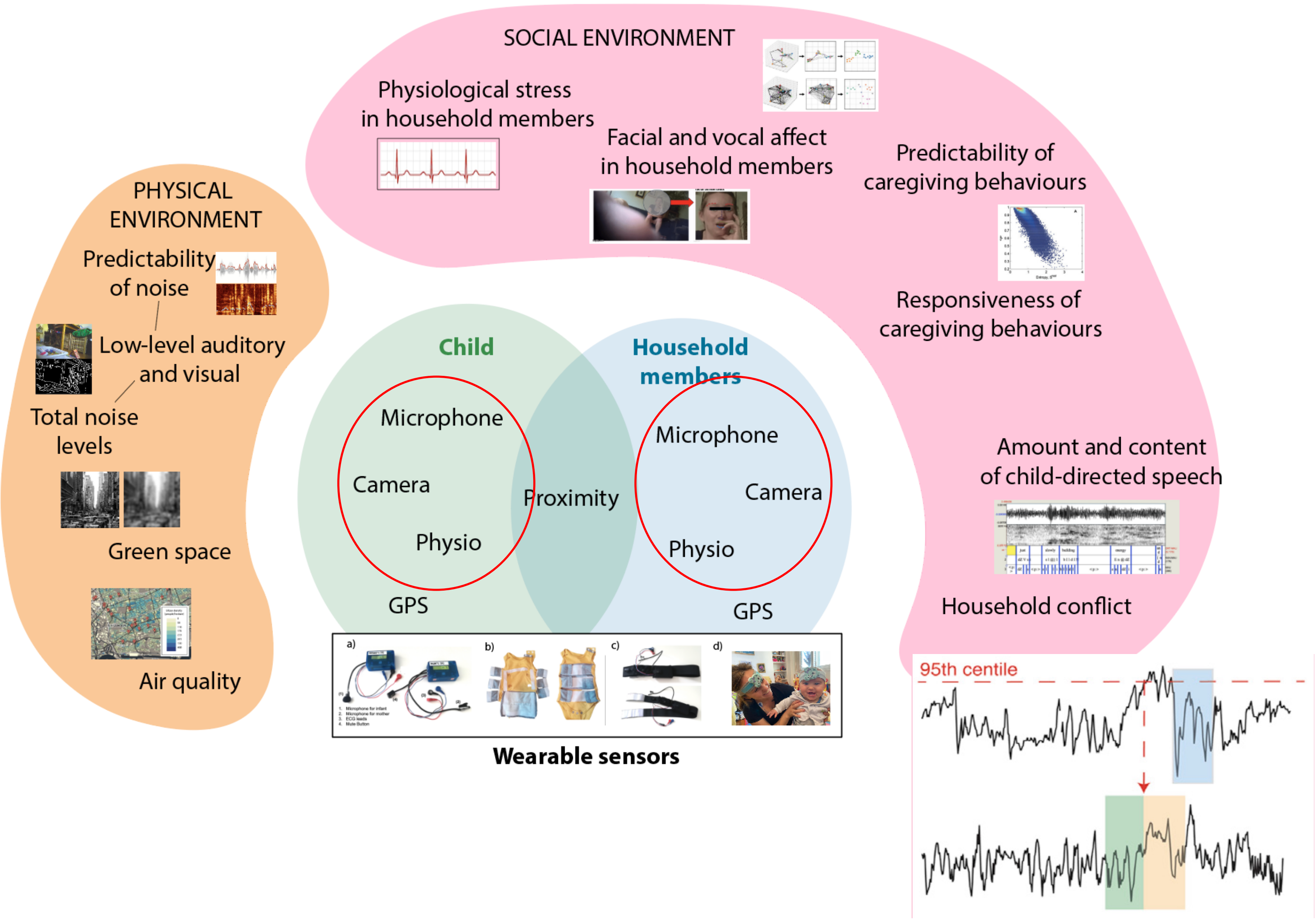


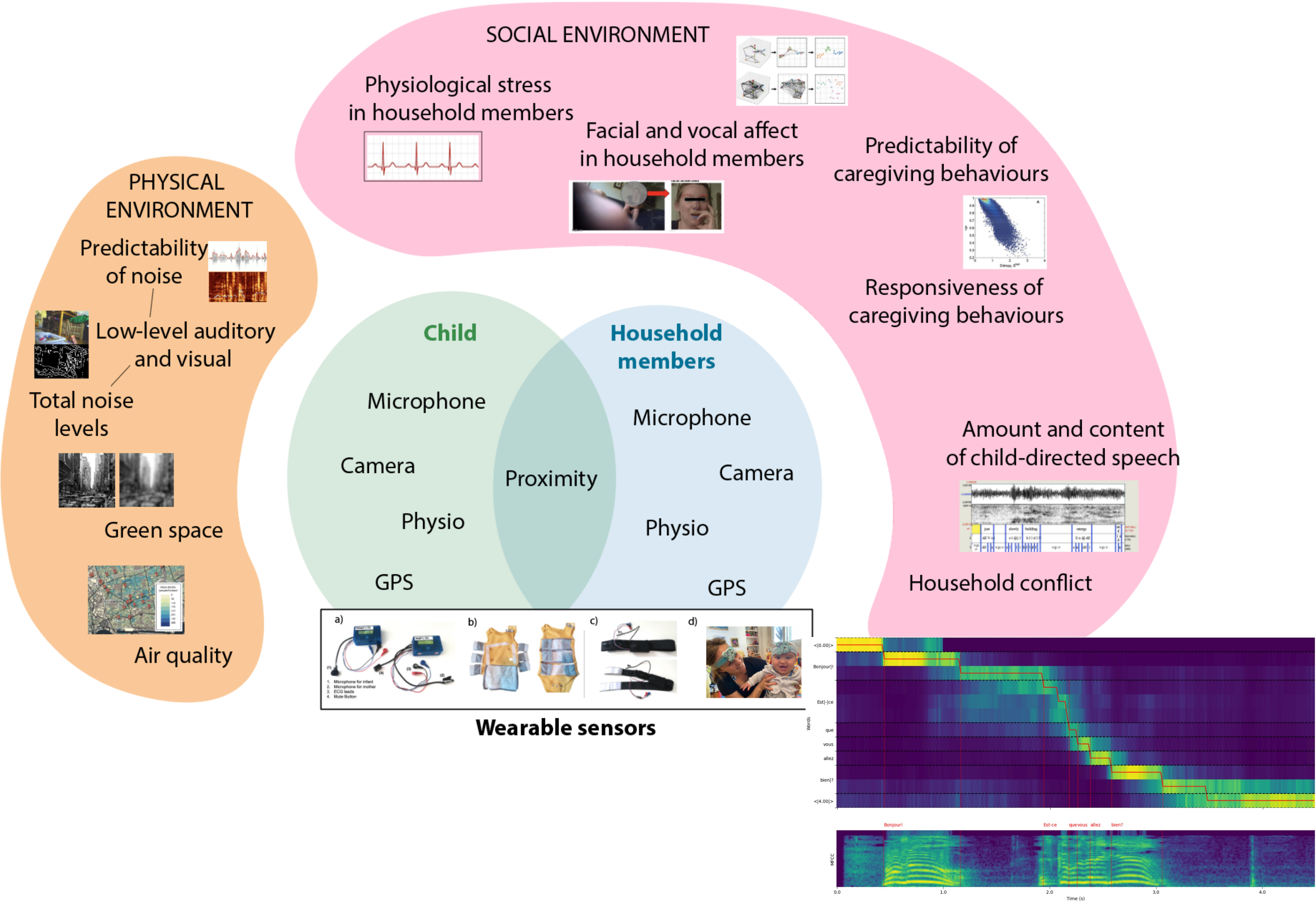
drive round pick my chil dren back up
PHYSICAL ENVIRONMENT
Predictability of noise
Low-level auditory and visual
Total noise levels
Green space
Air quality
Child
Household members
Microphone
Camera
Physio
GPS
Proximity
Microphone
Camera
Physio
GPS
a)
b)
c)
d)
Wearable sensors
NEWHAM
Urban density (people/hectare)
0
58
116
175
233
291
150
408

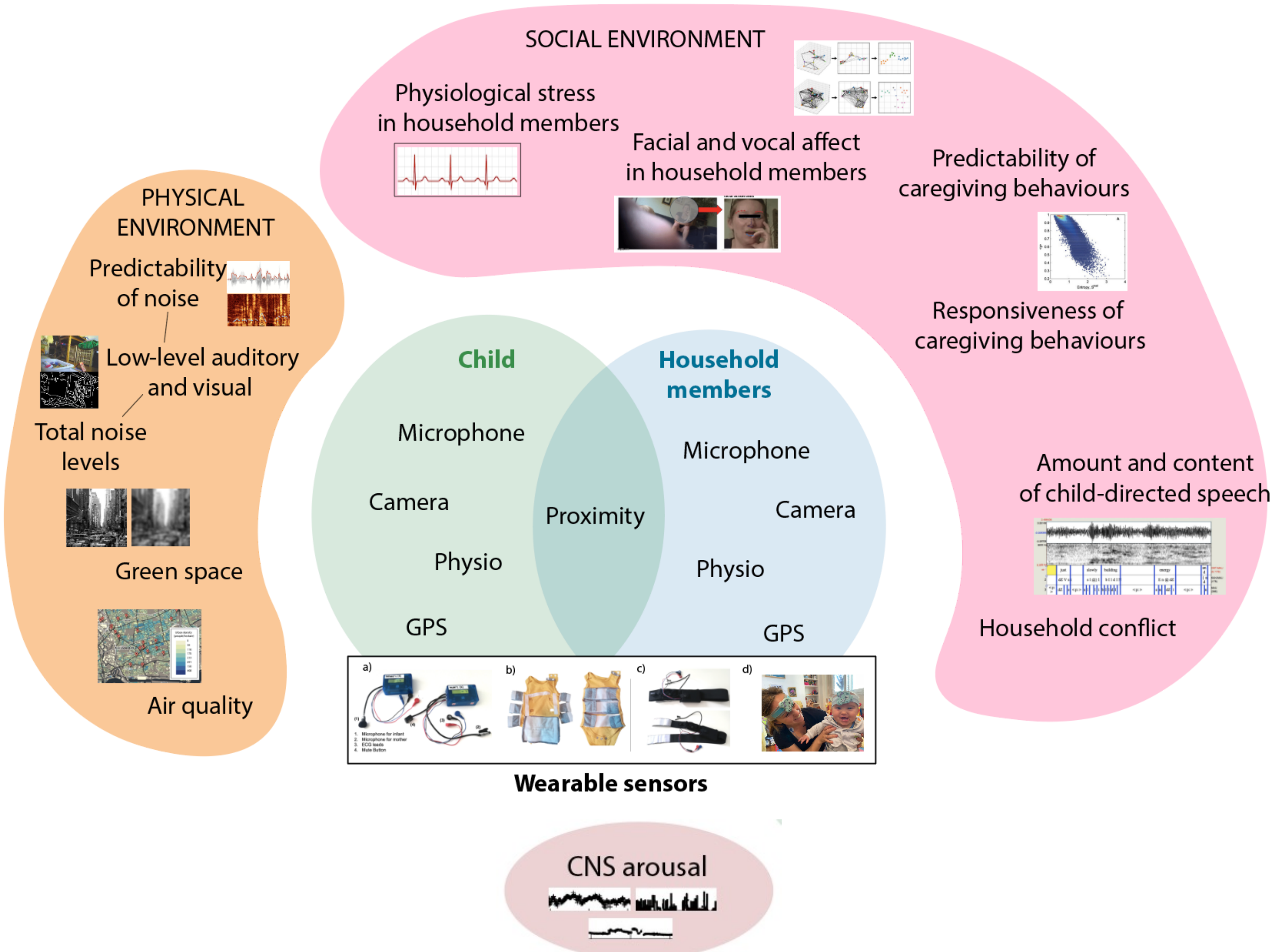

SOCIAL ENVIRONMENT
Physiological stress in household members
Facial and vocal affect in household members
Predictability of caregiving behaviours
Responsiveness of caregiving behaviours
Amount and content of child-directed speech
Household conflict
PHYSICAL ENVIRONMENT
Predictability of noise
Low-level auditory and visual
Total noise levels
Green space
Air quality
Child
Microphone
Camera
Physio
GPS
Proximity
Household members
Microphone
Camera
Physio
GPS
a)
b)
c)
d)
Wearable sensors

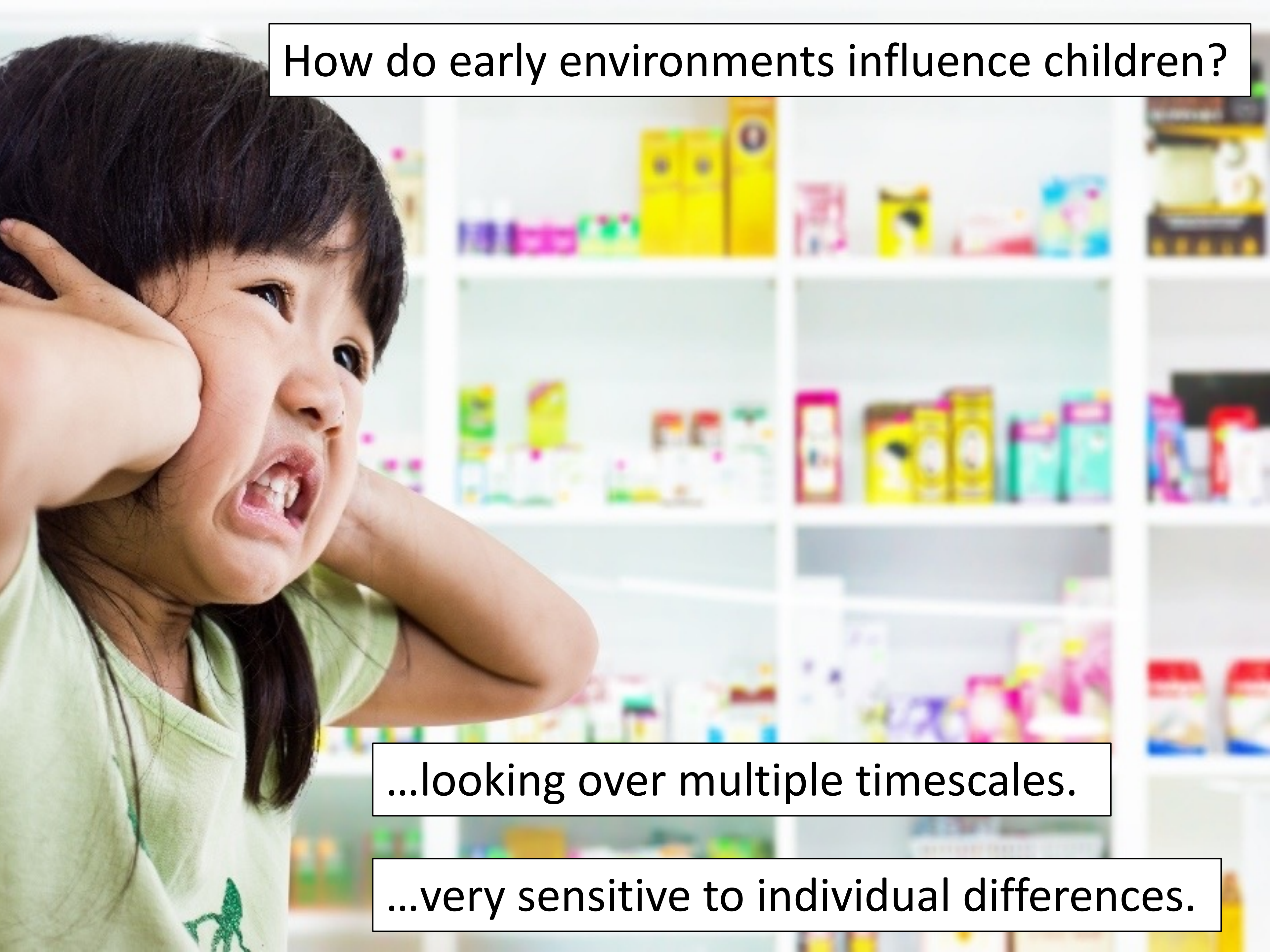


SOCIAL ENVIRONMENT
Physiological stress in household members
Facial and vocal affect in household members
Predictability of caregiving behaviours
Responsiveness of caregiving behaviours
Amount and content of child-directed speech
Household conflict
PHYSICAL ENVIRONMENT
Predictability of noise
Low-level auditory and visual
Total noise levels
Green space
Air quality
Child
Microphone
Camera
Physio
GPS
Proximity
Household members
Microphone
Camera
Physio
GPS
Wearable sensors


SOCIAL ENVIRONMENT
Physiological stress in household members
Facial and vocal affect in household members
Predictability of caregiving behaviours
Responsiveness of caregiving behaviours
Amount and content of child-directed speech
Household conflict
95th centile
PHYSICAL ENVIRONMENT
Predictability of noise
Low-level auditory and visual
Total noise levels
Green space
Air quality
Child
Household members
Microphone
Camera
Physio
GPS
Proximity
Microphone
Camera
Physio
GPS
a)
b)
c)
d)
Wearable sensors


SOCIAL ENVIRONMENT
Physiological stress in household members
Facial and vocal affect in household members
Predictability of caregiving behaviours
Responsiveness of caregiving behaviours
Amount and content of child-directed speech
Household conflict
PHYSICAL ENVIRONMENT
Predictability of noise
Low-level auditory and visual
Total noise levels
Green space
Air quality
Child
Household members
Microphone
Camera
Physio
GPS
Proximity
Microphone
Camera
Physio
GPS
a)
b)
c)
d)
Wearable sensors
Bonjour!
Est-ce
que
vous
allez
bien?
Words
MFCC
Time (s)


SOCIAL ENVIRONMENT
Physiological stress in household members
Facial and vocal affect in household members
Predictability of caregiving behaviours
Responsiveness of caregiving behaviours
Amount and content of child-directed speech
Household conflict
PHYSICAL ENVIRONMENT
Predictability of noise
Low-level auditory and visual
Total noise levels
Green space
Air quality
Child
Microphone
Camera
Physio
GPS
Proximity
Household members
Microphone
Camera
Physio
GPS
a)
b)
c)
d)
Wearable sensors
CNS arousal


How do early environments influence children?
…looking over multiple timescales.
…very sensitive to individual differences.

Our aim

Make this technology suitable for use with neurodevelopmental populations

The Team

Dr Marwa Mahmoud
(Glasgow, Computer Scientist)

Prof Pasco Fearon
(Cambridge, Clinician)

Prof Carlo Schuengel
(Amsterdam, Clinicial Child and Family Studies)

Jeremy Curtis
(Cambridge, Electrical Engineer)

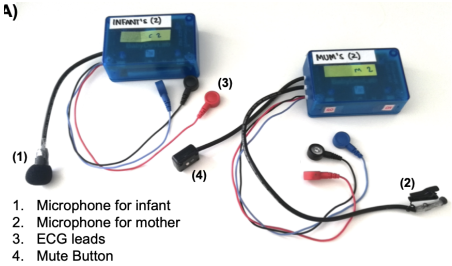
Gemma Goldenberg
(London, Parent of neurodivergent children)

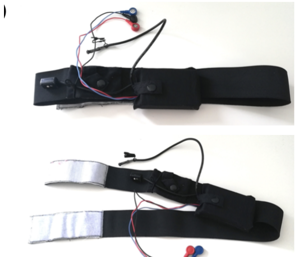
Main objectives

1 Hardware

- Optimise current devices for use with neurodivergent children

- Optimise current clothing for use with neurodivergent children

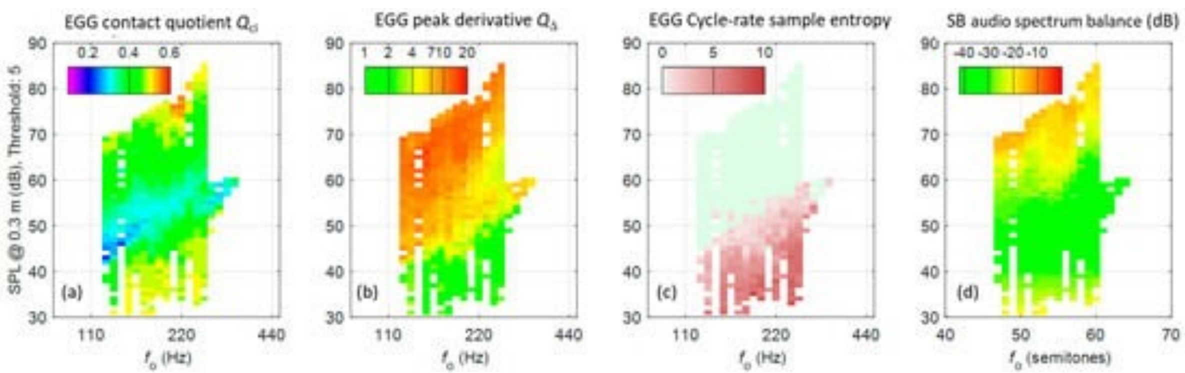




Main objectives

2 Software

- Change current analysis packages to ensure suitability for neurodivergent children (e.g. optimising vocalisation detection algorithms for children with ASC)
- Make analysis packages open-source and suitable e.g. for use with clinicians



Main objectives

3 Ethical implications

- security, privacy and safeguarding issues, ensuring that the special needs of neurodivergent children are met

Current and future funding plans

N=600 longitudinal dataset funded by UKRI (ESRC, MRC) and the European Research Council from mostly typical population aged 4 months to 6 years and their caregivers (Wass/Jones)

Current and future funding plans

N=600 longitudinal dataset funded by UKRI (ESRC, MRC) and the European Research Council from mostly typical population aged 4 months to 6 years and their caregivers (Wass/Jones)

COST Action – European networks for studying environmental variability

Current and future funding plans

N=600 longitudinal dataset funded by UKRI (ESRC, MRC) and the European Research Council from mostly typical population aged 4 months to 6 years and their caregivers (Wass/Jones)

COST Action – European networks for studying environmental variability

ESRC Early Life Cohort Study

Current and future funding plans

N=600 longitudinal dataset funded by UKRI (ESRC, MRC) and the European Research Council from mostly typical population aged 4 months to 6 years and their caregivers (Wass/Jones)

COST Action – European networks for studying environmental variability

ESRC Early Life Cohort Study

…open to suggestions for possible studies involving neurodivergent children!!

Current and future funding plans

N=600 longitudinal dataset funded by UKRI (ESRC, MRC) and the European Research Council from mostly typical population aged 4 months to 6 years and their caregivers (Wass/Jones)

COST Action – European networks for studying environmental variability

ESRC Early Life Cohort Study

…open to suggestions for possible studies involving neurodivergent children!!

> Understanding individual differences in sensitivity to environmental features
>
> Personally tailored environments/interventions

MENTION TEAM MORE

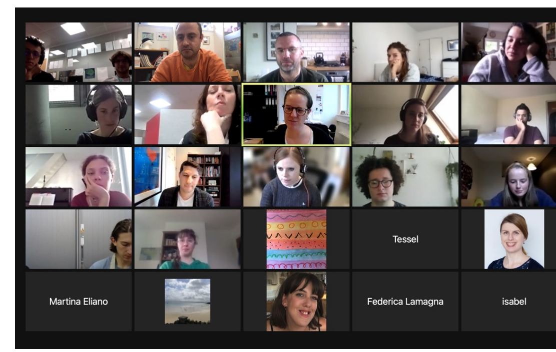
UKRI Medical Research Council

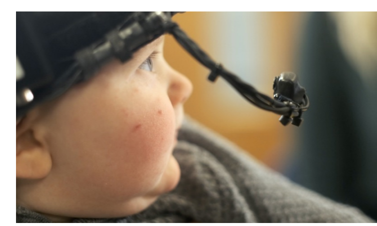
UKRI Economic and Social Research Council

erc

UEL BABY DEV LAB

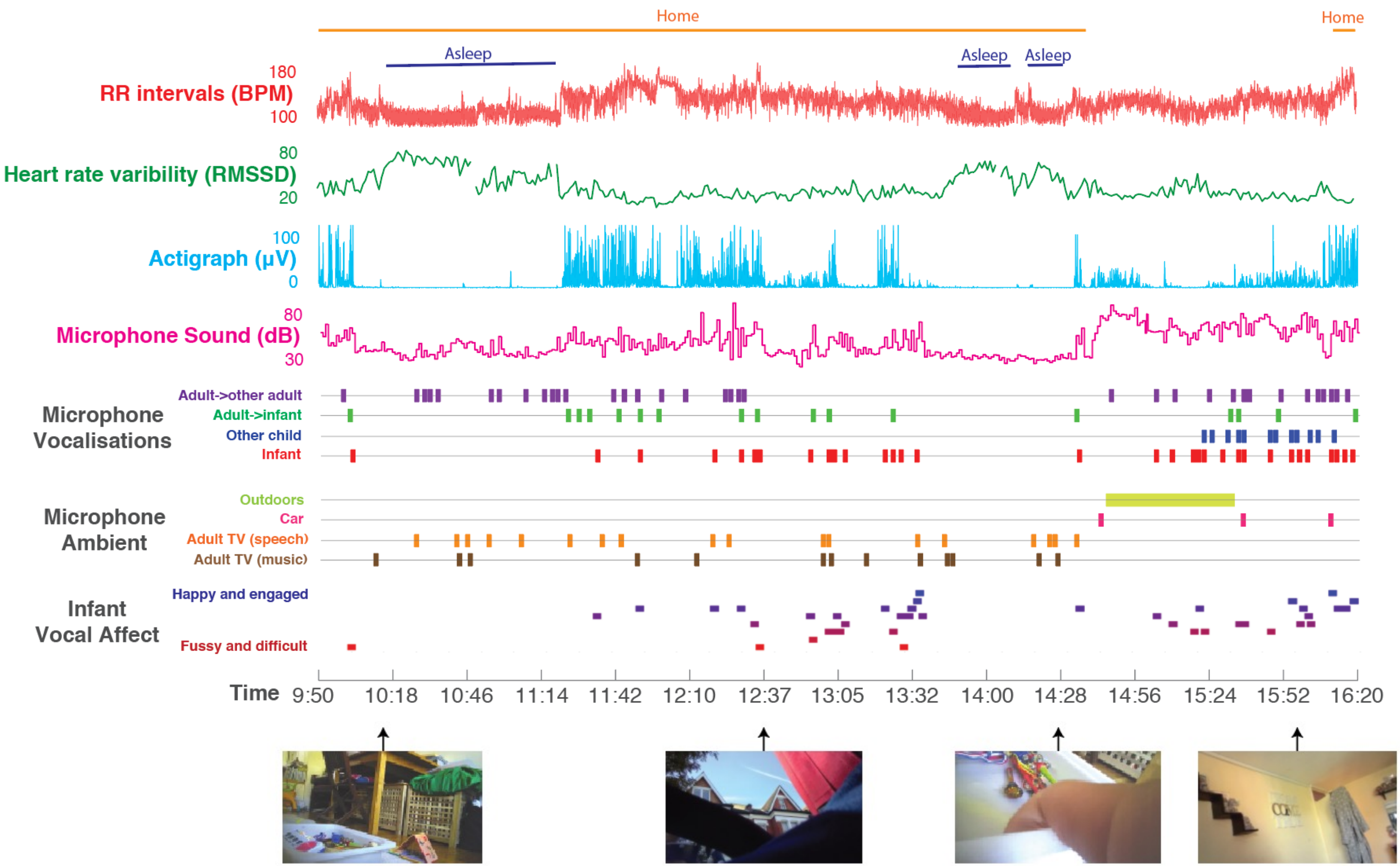
www.uelbabydev.com





Prof Sam Wass
s.v.wass@uel.ac.uk
twitter @profsamwass

Thank you!


Home
Home
Asleep
Asleep
Asleep
180
RR intervals (BPM)
100
80
Heart rate varibility (RMSSD)
20
100
Actigraph (μV)
0
80
Microphone Sound (dB)
30
Microphone Vocalisations
Adult->other adult
Adult->infant
Other child
Infant
Microphone Ambient
Outdoors
Car
Adult TV (speech)
Adult TV (music)
Infant Vocal Affect
Happy and engaged
Fussy and difficult
Time
9:50
10:18
10:46
11:14
11:42
12:10
12:37
13:05
13:32
14:00
14:28
14:56
15:24
15:52
16:20

Economic and Social Research Council

European Research Council
Established by the European Commission

Journal of Child Psychology and Psychiatry **:* (2019), pp **–** doi:10.1111/jcpp.13084

Influences of environmental stressors on autonomic function in 12-month-old infants: understanding early common pathways to atypical emotion regulation and cognitive performance

Sam V. Wass,[1] Celia G. Smith,[2] Katie R. Daubney,[1] Zeynep M. Suata,[2] Kaili Clackson,[3] Abdul Begum,[1] and Farhan U. Mirza[4]

[1]School of Psychology, University of East London, London; [2]Institute of Psychiatry, Psychology and Neuroscience, King's College London, London; [3]Department of Experimental Psychology, University of Cambridge, Cambridge; [4]School of Health Professions, University of Plymouth, Plymouth, UK

Background: Previous research has suggested that children exposed to more early-life stress show worse mental health outcomes and impaired cognitive performance in later life, but the mechanisms subserving these relationships remain poorly understood. **Method:** Using miniaturised microphones and physiological arousal monitors (electrocardiography, heart rate variability and actigraphy), we examined for the first time infants' autonomic reactions to environmental stressors (noise) in the home environment, in a sample of 82 12-month-old infants from mixed demographic backgrounds. The same infants also attended a laboratory testing battery where attention- and emotion-eliciting stimuli were presented. We examined how children's environmental noise exposure levels at home related to their autonomic reactivity and to their behavioural performance in the laboratory. **Results:** Individual differences in total noise exposure were independent of other socioeconomic and parenting variables. Children exposed to higher and more rapidly fluctuating environmental noise showed more unstable autonomic arousal patterns overall in home settings. In the laboratory testing battery, this group showed more labile and short-lived autonomic changes in response to novel attention-eliciting stimuli, along with reduced visual sustained attention. They also showed increased arousal lability in response to an emotional stressor. **Conclusions:** Our results offer new insights into the mechanisms by which environmental noise exposure may confer increased risk of adverse mental health and impaired cognitive performance during later life. **Keywords:** Environmental noise; autonomic nervous system; arousal; infant; attention.

Introduction

One well-replicated finding within psychology and psychiatry is that early exposure to stressful environments increases the risk of adverse long-term outcomes, including mental disorder (Businelle et al., 2013; Felitti et al., 1998) and cognitive impairment (Blair, 2010; Evans & Schamberg, 2009). Recent research has suggested that the increased mental health risk conferred by early-life stress is transdiagnostic, and not disorder-specific (Conway, Raposa, Hammen, & Brennan, 2018), offering some vital clues as to aetiological pathways (Karmiloff-Smith, 1998). Early-developing impairments in brainstem-mediated arousal and regulation circuits may act as a common pathway, causing developmental impairments in domains such as socioemotional self-regulation, inhibitory control, executive, verbal and motor functions, and cognitive processing (Geva & Feldman, 2008). Even minor alterations in responses to daily stressors may trigger a cascade of changes which cumulatively constitute a vulnerability to or risk factor for later psychopathology (Borsboom & Cramer, 2013; Charles, Piazza, Mogle, Sliwinski, & Almeida, 2013; Sonuga-Barke, Koerting, Smith, McCann, & Thompson, 2011; Trull, Lane, Koval, & Ebner-Priemer, 2015; Wichers, Wigman, & Myin-Germeys, 2015).

Stress is an umbrella term used to refer to actual life events or situations ('stressors') and to the cognitive and biological responses that such situations evoke ('stress responses') (Epel et al., 2018). Both aspects can be studied over multiple timescales. Stressors range from lifelong factors (e.g. poverty) to short-term ones (e.g. a cup of tea spilled on a laptop); stress responses diversely include both long- and slow-acting changes in diverse endocrine and nervous systems designed to help an organism maintain homeostasis and allostasis in the face of change (Cannon, 1915; McCall et al., 2015; Selye, 1951).

Within psychology and psychiatry, researchers generally measure early-life stress using questionnaire assessments that identify lifelong stressors, such as parental conflict and emotional abuse (Felitti et al., 1998). Over recent years, we are increasingly becoming aware that short-term factors, such as environmental noise, also cause stress responses. Understanding these is particularly important given our current rapid urbanisation as a species, with concomitant increase in noisy and cramped living environments (Evans, 2004).

Nonauditory effects of noise are known to occur at levels far below those required to damage hearing

Conflict of interest statement: No conflicts declared.

Published by John Wiley & Sons Ltd, 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main St, Malden, MA 02148, USA

Please cite this article in press as: Wass et al., Parents Mimic and Influence Their Infant's Autonomic State through Dynamic Affective State Matching, Current Biology (2019), https://doi.org/10.1016/j.cub.2019.06.016

Current Biology

Report

CellPress

Parents Mimic and Influence Their Infant's Autonomic State through Dynamic Affective State Matching

Samuel Vincent Wass,[1,5,*] Celia Grace Smith,[2] Kaili Clackson,[3] Caitlin Gibb,[1] Joan Eitzenberger,[1] and Farhan Umar Mirza[4]

[1]Department of Psychology, University of East London, Water Lane, London E15 4LZ, UK
[2]Institute of Psychiatry, Psychology and Neuroscience, King's College London, 16 De Crespigny Park, London SE5 8AF, UK
[3]Department of Experimental Psychology, University of Cambridge, Downing Street, Cambridge CB2 3EB, UK
[4]School of Health Professions, University of Plymouth, Derriford Road, Plymouth PL6 8BH, UK
[5]Lead Contact
*Correspondence: s.v.wass@uel.ac.uk
https://doi.org/10.1016/j.cub.2019.06.016

SUMMARY

When we see someone experiencing an emotion, and when we experience it ourselves, common neurophysiological activity occurs [1, 2]. But although inter-dyadic synchrony, concurrent and sequential [3], has been identified, its functional significance remains inadequately understood. Specifically, how do influences of partner A on partner B reciprocally influence partner A? For example, if I am experiencing an affective state and someone matches their physiological state to mine, what influence does this have on me—the person experiencing the emotion? Here, we investigated this using infant-parent dyads. We developed miniaturized microphones to record spontaneous vocalizations and wireless autonomic monitors to record heart rate, heart rate variability, and movement in infants and parents concurrently in naturalistic settings. Overall, we found that infant-parent autonomic activity did not covary across the day—but that "high points" of infant arousal led to autonomic changes in the parent and that instances where the adult showed greater autonomic responsivity were associated with faster infant quieting. Parental responsivity was higher following peaks in infant negative affect than in positive affect. Overall, parents responded to increases in their child's arousal by increasing their own. However, when the overall arousal level of the dyad was high, parents responded to elevated child arousal by decreasing their own arousal. Our findings suggest that autonomic state matching has a direct effect on the person experiencing the affective state and that parental co-regulation may involve both connecting and disconnecting their own arousal state from that of the child contingent on context.

RESULTS

Since John Donne asserted that "no man [or woman] is an Iland, intire of itselfe" [4], many researchers have followed him in operationalizing affective states not as private mental concepts but rather as properties that "resonate" [5] in "interpersonal" space [6–9]. Certainly, we know that common patterns of neurophysiological activity occur when we observe someone else experiencing emotional states, such as disgust or pain, and when we experience them ourselves, e.g. [1, 2]. But we understand little about how these time-lagged interpersonal influences, sometimes characterized formally as "sender-receiver" relationships [10], influence functions such as emotion regulation, which are usually considered from an endogenous perspective [3, 5, 8, 11, 12].

To address this question, we developed miniaturized microphones, electrocardiograms, and actigraphs to record vocalizations and track both infants' and parents' autonomic changes across the day in home settings (Figures 1A and 1B). We examined how adult and infant arousal levels co-fluctuate during the day (concurrent synchrony) [3] and whether changes in the infant's arousal forward-predict changes in the parent's and vice versa (sequential synchrony) [13]. We examined whether these bidirectional parent-child influences were present across all data analyzed (analysis 2) or limited to moments of peak arousal in the infant (analysis 3) and whether they were stronger during negative or positive infant affect (analyses 3 and 4). We also examined whether parental responsivity to a "peak" arousal event predicted infants' subsequent recovery (analysis 5). Finally, we examined how parents' responsiveness to arousal changes in their child varied contingent on the parent's initial level of arousal (analysis 6).

Descriptive Analyses—Analysis 1

Figures 2A–2C show descriptive plots of our data.

Concurrent Synchrony in Parent-Infant Arousal—Analysis 2

We conducted a cross-correlation analysis [13–15] to examine whether, across all samples, there is an association between the parent's arousal level and the infant's. This analysis (Figure S2) identified only a weak, non-significant ($p = 0.15$) association between parents' arousal levels and their infant's. This suggests that autonomic activity between infants and parents does not covary across the day.

This finding leaves open the possibility that associations between a parent's and infant's arousal levels are present at certain