Implementing a new platform to test empathy in toddlers with wearable fNIRS in freely moving set-up

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LEVERHULME TRUST

BACKGROUND

- **Empathy** (i.e. sharing others' feelings) is fundamental to build bonds between people[1].
- As failures of empathy may develop into persistent **antisocial behaviours**[2], understanding how empathy develops is essential for early interventions.
- The ability to identify whether emotions originate from oneself or others emerges in toddlerhood[3].
- We known little about empathy in toddlers because **we lack suitable experimental approaches**, as toddlers hardly comply with traditional lab testing.
- By leveraging the **Cave Automatic Virtual Environment (CAVE)** at the Birkbeck ToddlerLab, we will address the urgent need for **new methodologies to assess neural and physiological underpinning of empathy** in toddlers.
- We will record toddlers' brain activations using **functional near-infrared spectroscopy (fNIRS)** and **physiological indicators of arousal (perspiration and heart rate) using a BIOPAC system** (the grey box shows the validation of a wearable Artinis fNIRS system for its use in the CAVE).
- In <u>phase 1</u> we will i) pilot a **standard block design** to study empathy, ii) investigate the **level of engagement with different avatars** (age and sex) in the CAVE on 30 3-to-5-year-olds. In <u>phase 2</u>, the avatar which toddlers engaged the most with will be used to interact with toddlers in the CAVE. Signatures of cognitive and emotional empathy[4] acquired during avatar-toddler interactions in the CAVE will be compared to those acquired during the standard block design (Fig. 1).

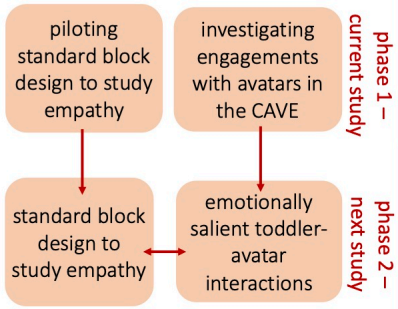

Fig. 1. The first two phases of the project.

PRELIMINARY DATA

validation of a wearable fNIRS system for its use in the CAVE

- We assessed the **feasibility of wearable fNIRS** in monitoring the functional specialization to social cues in 43 3-to- 5-year-old toddlers presented with social and non-social stimuli[5].
- Changes in cortical haemodynamic were monitored over the right and left frontal and temporal lobes using a wearable fNIRS system (Brite24, Artinis Medical Systems, The Netherland) (Fig.2).

Fig. 2. A 3-year-old wearing the wearable fNIRS system

- Channels with insufficient correlation between wavelengths and without a clear heart-rate peak were pruned[6] and motion artefacts were corrected using spline interpolation and wavelet[7].
- Attrition rates were lower than typical fNIRS infants' experiments (~34.23%) (Fig.3A); clear hemodynamic responses were observed over the temporal lobe (Fig.3B).

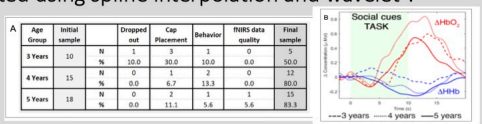

Fig. 3. A) Attrition rates; B) Neural activation in brain regions associated with social processing.

- Good quality fNIRS data can be recorded with wearable fNIRS on toddlers. The absence of long fibre bundles **increased the children's tolerance to the cap and reduced motion artefacts, resulting in a higher number of trials, statistical power, and signal quality.**

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TASKS DESIGN – PHASE 1

STANDARD BLOCK DESIGN

TASK

Empathic scenarios with a voice describing the story

DEPENDENT VARIABLES

how does he feel?

COGNITIVE EMPATHY
understanding the other's feeling

EMOTIONAL EMPATHY
sharing the other's feeling

fNIRS arousal

CAVE

Toddler playing in a virtual playground in the CAVE

Avatars taken from www.cgtrader.com

Playing "popping bubbles" with a boy, a girl, a men and a woman

ENGAGEMENT

how much time the played with each avatars

how many bubbles popped from each avatar

WHAT WILL HAPPEN IN PHASE 2?

- We will create **emotionally salient social avatar-toddler interactions** in the CAVE with the avatar which toddlers engaged the most with in phase 1. (Fig. 4)
- In the CAVE, as scenarios are more realistic, toddlers will likely feel the **first-person experience typical of empathy**.
- We hypothesise that the CAVE set-up will elicit **greater underpinnings of empathy and a clearer distinction of cognitive and emotional empathy** than the standard block design.

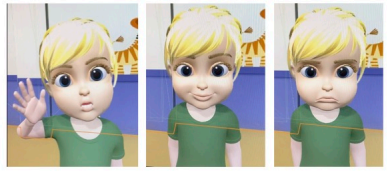

Fig.4 The avatar Amy waiving, smiling and being sad.

ANALYSIS OF THE fNIRS SIGNAL DURING AVATAR-TODDLER INTERACTIONS IN PHASE 2

- fNIRS signal will be recorded from the **medial (mPFC) and dorsal prefrontal cortex (dPFC)** and **temporoparietal junction (TPJ)** (Fig.5) during toddler-avatar interactions in the CAVE.
- Channels will be pruned and motion artefacts will be corrected as previously done (see grey box on the left).
- Haemodynamic responses locked to **emotionally and non-emotionally salient events** will be recovered and averaged over the same condition.

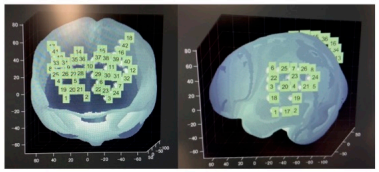

Fig. 5. Localisation of the fNIRS channels of the array used in this project

- We will estimate the features of the toddlers' HRF in the pilot study and using it to apply GLM-based analyses in this task.
- **Brain connectivity analyses** → we will estimate the modulation of the mPFC and dPFC over the TPJ using DCM analyses[8]. We will investigate whether emotional and cognitive empathy will activate different networks of regions[9].
- We will integrate measures of neural underpinning of empathy with physiological indicator of arousal and behavioural measures collected during the task.

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