



# From Signals to Support: A Classroom-Scale Biometric–Facial Research Platform for Inclusive Education

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## Introduction

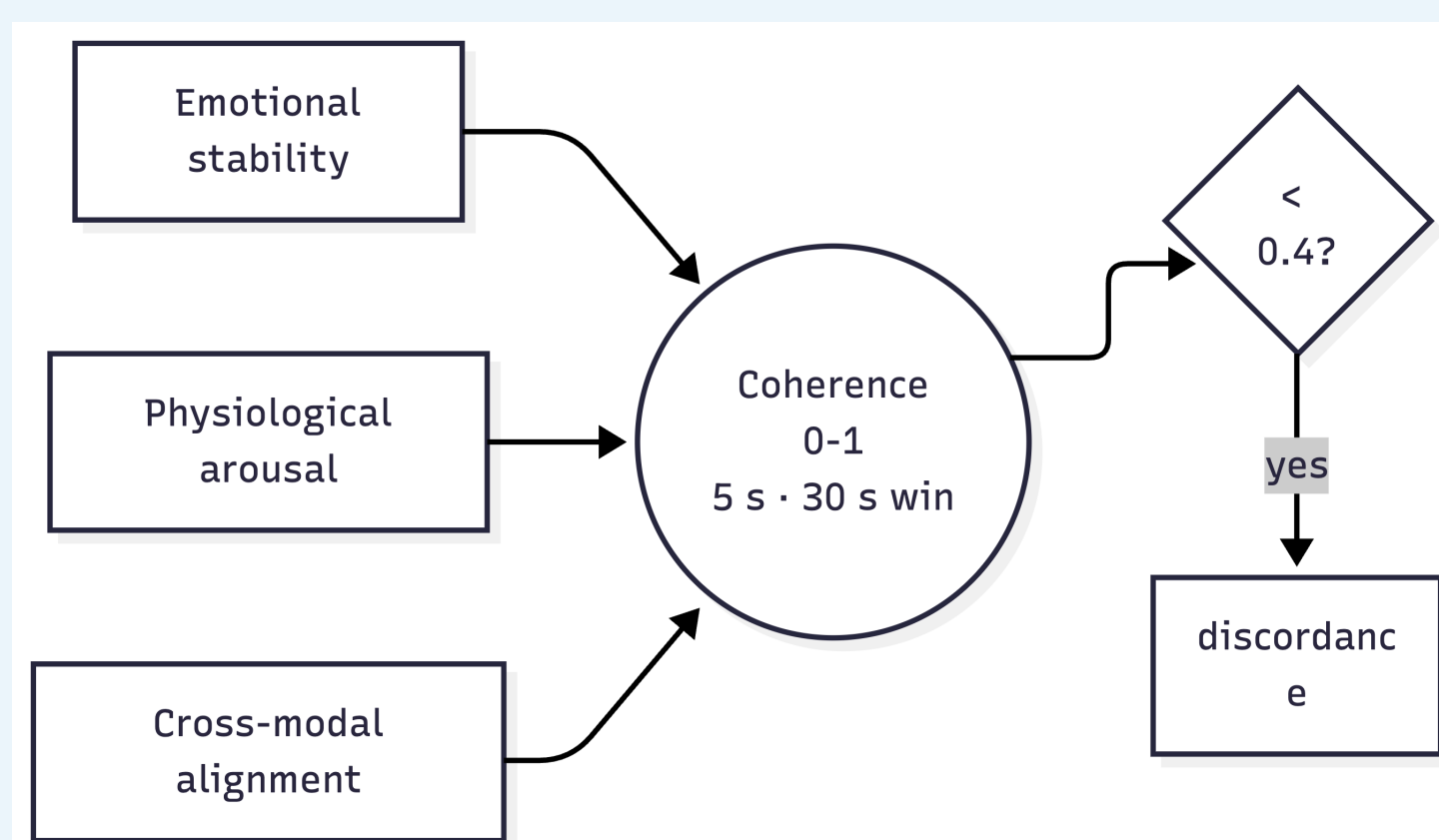
War has left millions of Ukrainian children with unresolved trauma, often masked as emotional calm while autonomic arousal remains high. Teachers have no real-time tool to detect this gap; periodic assessments arrive too late and unaided observation misses suppressed expressions [1, 7].

**BioMirror Researcher** bridges this gap: a macOS companion app that extends the existing iOS single-device prototype into a **30-student classroom-scale research instrument**, integrating with art therapy and play-based learning in Ukrainian inclusive schools [10].

## The BioMirror Platform

Each student uses an **iPhone + Apple Watch**: ARKit reads 52 facial blend-shapes at 60 fps (7-class emotion, 500 ms micro-expression); Watch streams HR, HRV/SDNN, temperature, and respiration. The **coherence score** (0–1) merges these streams every 5 s over a 30 s window—low score signals masking or dissociation; inference is *on-device* and no images leave the phone. The macOS **Researcher** supervises up to **30 devices** via Bonjour/mDNS and fires discordance alerts at threshold 0.4.

## Methods: Coherence Computation and Architecture (Fig. 1)



Three components combine every 5 s (30 s sliding window):

**(0.3) Emotional stability** — variance of emotion classification

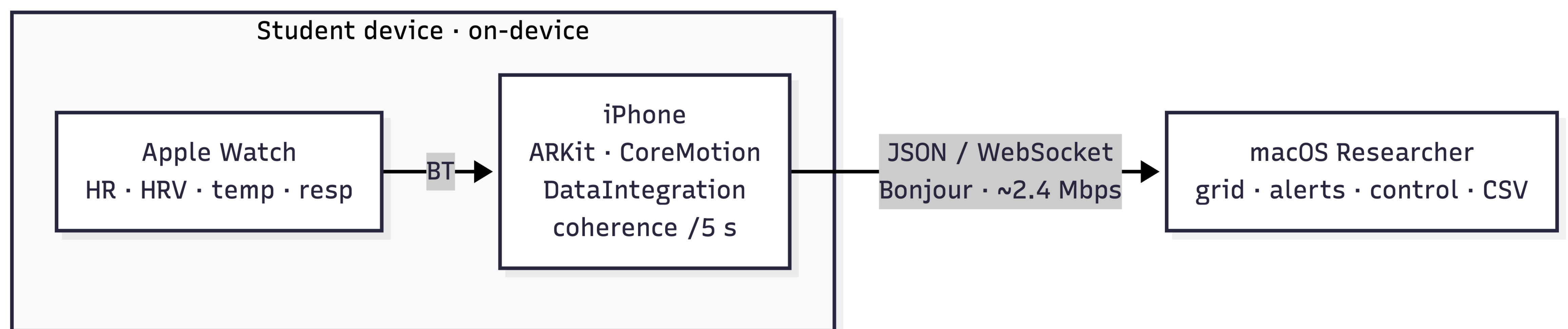
**(0.4) Physiological state** — HR / HRV / tremor / temperature composite

**(0.3) Cross-modal alignment** — Pearson correlation between smoothed emotion intensity and autonomic arousal index

A **discordance detector** (threshold 0.4) flags two patterns: *masking* (suppressed face + elevated arousal) and *dissociation* (suppressed face + suppressed HRV).

Session data persist to **Core Data on-device**. The macOS app discovers each iPhone via `_biomirror._tcp` (Bonjour) and receives `sessionUpdate` packets every 2 s (emotion class, HR, HRV, coherence) plus alert notifications; 30 devices use less than 3 Mbps total.

## BioMirror System Architecture (Fig. 2)



## Results: Key Performance Metrics (Adult Validation [4])

**87.3%**

Emotion recognition accuracy

**< 50 ms**

Cross-device synchronisation

**94%**

Biometric signal validity

**30**

Concurrent devices

**98.2%**

WebSocket uptime (4 h)

**< 3 Mbps**

Bandwidth (30 devices)

## Proposed Deployment in Ukrainian Inclusive Schools (Figs. 3 & 4)

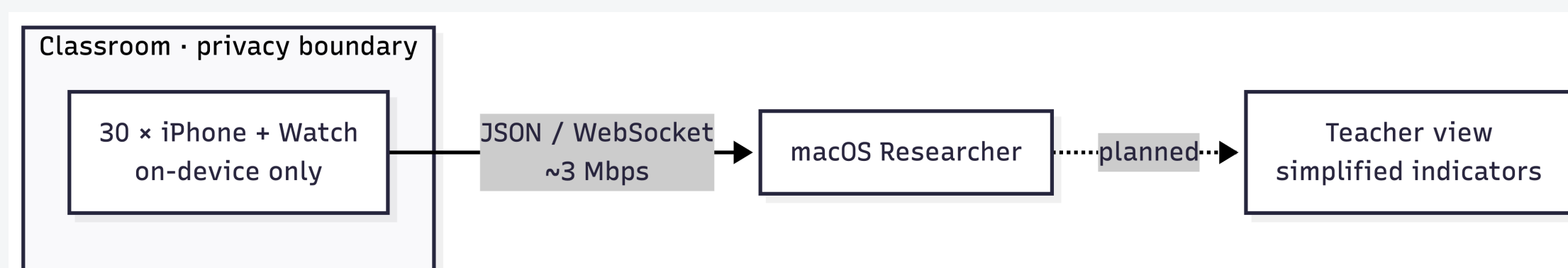


Fig. 3 — Classroom deployment, 30 students

Prep (4 wk): ethics, consent, Wi-Fi, teacher training. Data collection (8 wk): 2–3 art-therapy/play sessions per week, researcher monitors alerts. Analysis (4 wk): coherence distributions, group synchrony, teacher journals, interviews.

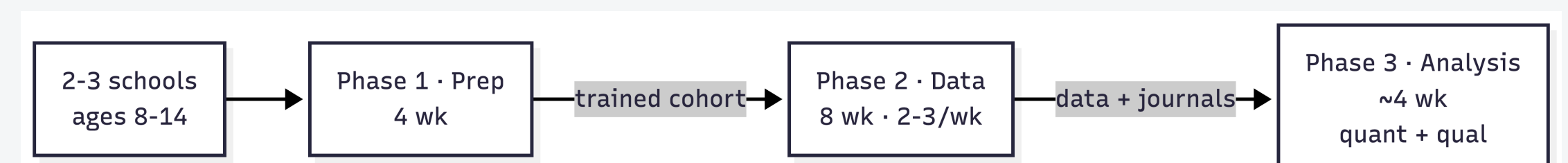


Fig. 4 — Three-phase pilot study design

## Conclusions

- Scales to **30 students** on school Wi-Fi: 87.3% emotion accuracy, <50 ms cross-device sync, 94% biometric signal validity.
- The **coherence score** detects masking and dissociation that remain invisible to unaided observation, enriching art therapy and play-based sessions.
- Automated distress alerts **reduce teacher workload**; a Watch-free mode is under development to address hardware cost.
- **Next step**: mixed-methods pilot in 2–3 Ukrainian inclusive schools (ages 8–14) integrating BioMirror with art therapy and play-based learning [10].

## Ethics and Safeguards

- **On-device only** — no facial images or raw blend-shape vectors leave the iPhone under any circumstances.
- Coherence scores stored under **pseudonymous IDs**; the identity mapping is held separately by the school administrator.
- Data **deleted** post-study; participation is voluntary and has no effect on student standing.
- Protocol approved by the ethics committee of Vasyl Stefanyk Carpathian National University.