Identifying Physiological-Emotional Response Patterns During Competitive Tasks

An Unsupervised Learning Analysis of the EmoPairCompete Dataset

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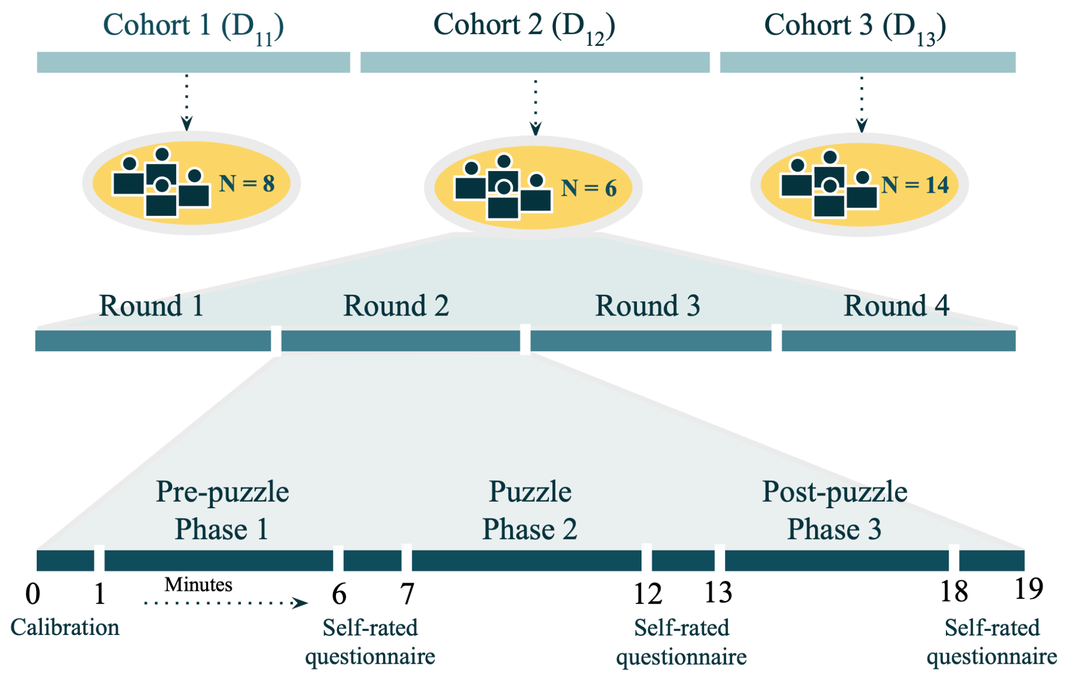
Research Question & Methodology

- “*Do distinct physiological-emotional response patterns exist among participants during competitive puzzle-solving tasks, and what characterises these different profiles?*”
- Data: EmoPairCompete dataset (26 participants, 4 rounds)
- Signals: HR, EDA (phasic/tonic), Temperature, self-reported emotions
- Method: Dimensionality reduction, feature engineering and clustering methods

Experimental Design

- Design: 4 rounds × 3 phases = 12 measurements per participant
- Each Round:
  - 1-min calibration
  - 5-min pre-puzzle rest (Phase 1)
  - 5-min puzzle task (Phase 2) - our focus
  - 5-min post-puzzle recovery (Phase 3)
- Measurements: E4 wristband + I-PANAS-SF questionnaires

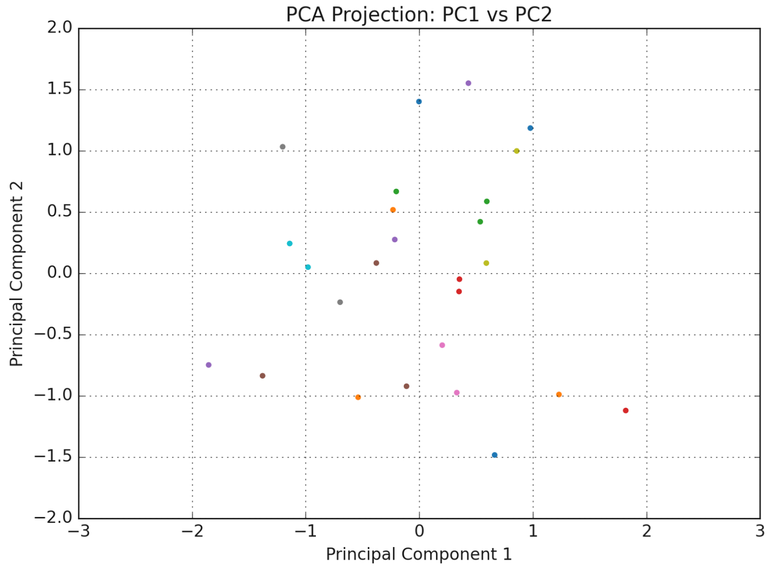


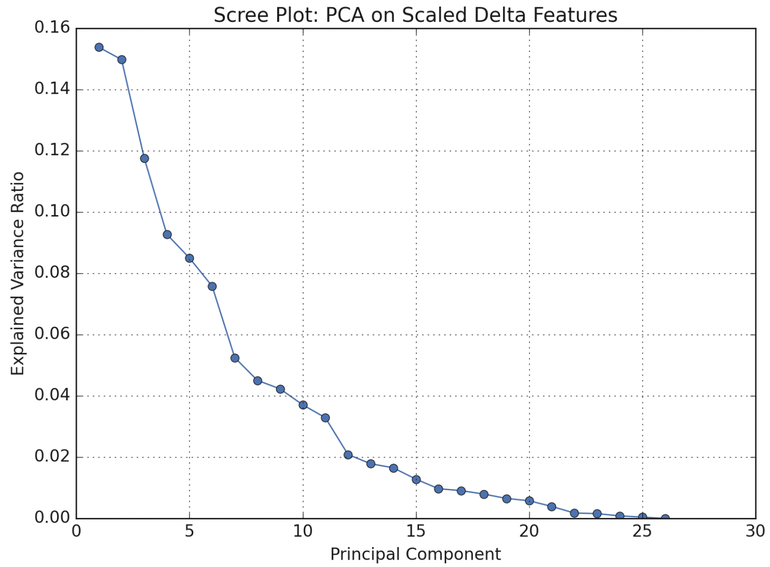
Data Processing

- Inverted temperature values (higher = more stress)
- Composite emotional scores: Positive Affect (PA) & Negative Affect (NA)
- Delta features: changes from baseline
- Scaled features for better comparison
- Select subset of features chosen for clustering

Principal Component Analysis (PCA)

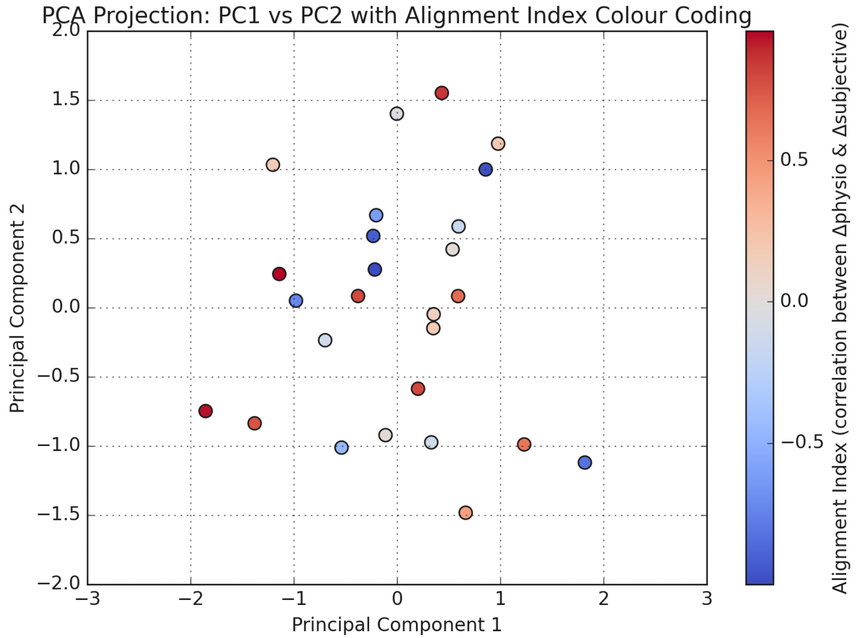
- Used to reduce dimensionality and identify main components of variation
- PC1 primarily associated with EDA measurements
- PC2 captured more variance in heart rate and temperature changes
- Built a PCA dataset using the top 6 principal components (70% of total variance explained)



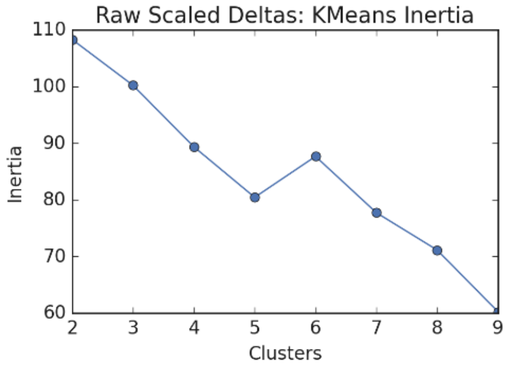


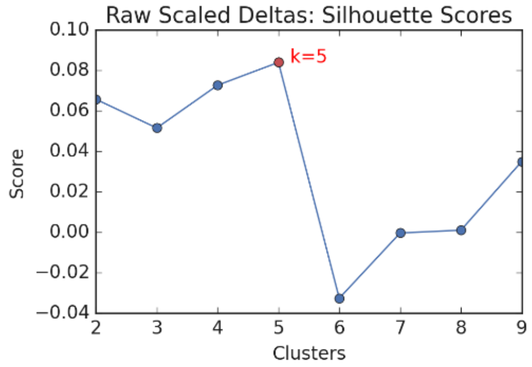
Alignment Index

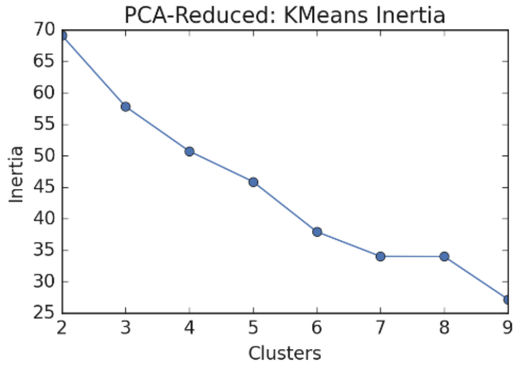
- Used to quantify the concordance between physiological and subjective emotional responses for each participant
- Range from -1 to +1
- Positive values indicate that physiological and subjective responses move in the same direction
- Negative values suggest a disconnect between bodily reactions and emotional awareness

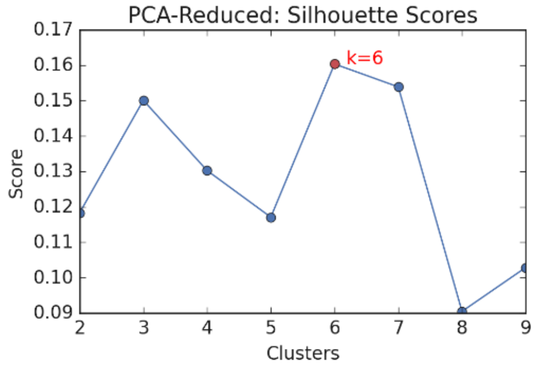


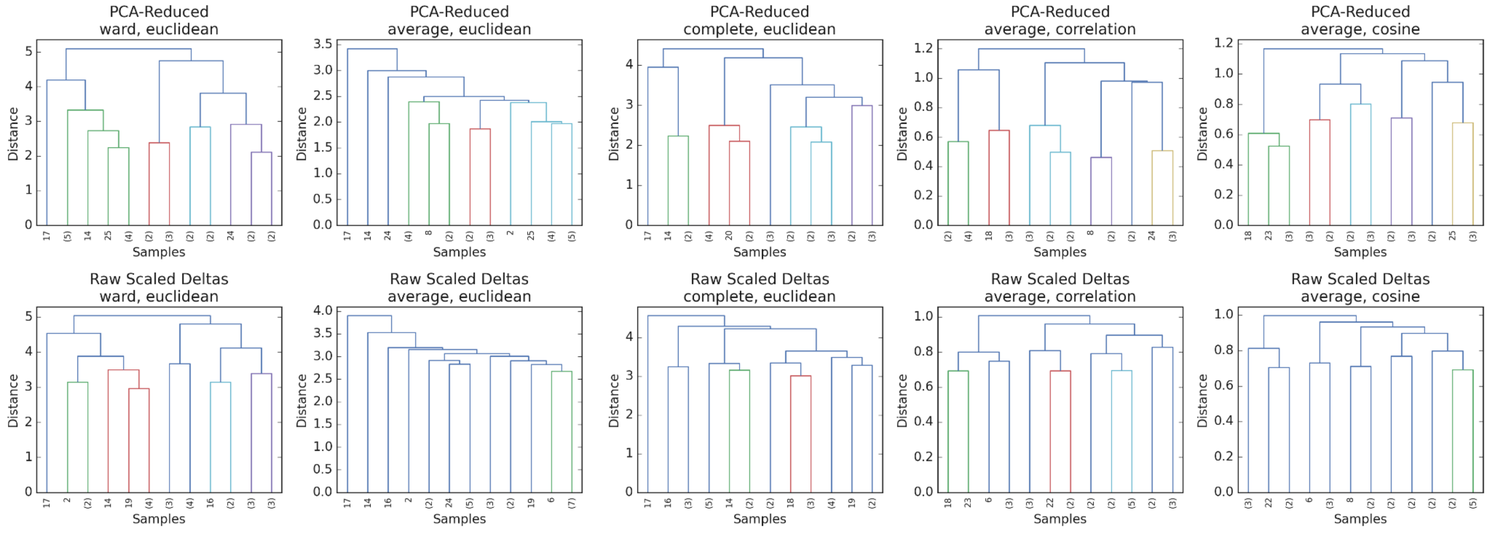
Clustering


Raw Scaled Deltas: KMeans Inertia
Inertia
Clusters


Raw Scaled Deltas: Silhouette Scores
k=5
Score
Clusters


PCA-Reduced: KMeans Inertia
Inertia
Clusters


PCA-Reduced: Silhouette Scores
k=6
Score
Clusters


PCA-Reduced
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PCA-Reduced
complete, euclidean
PCA-Reduced
average, correlation
PCA-Reduced
average, cosine
Raw Scaled Deltas
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Raw Scaled Deltas
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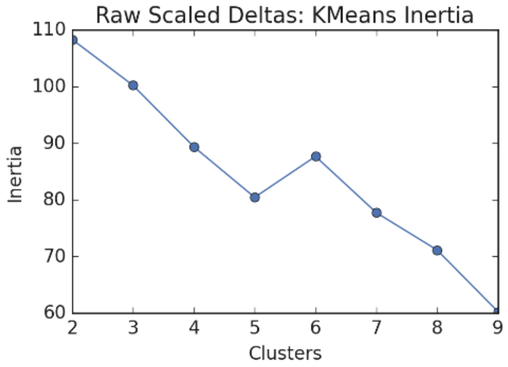
Raw Scaled Deltas
average, cosine
Distance
Samples

Clustering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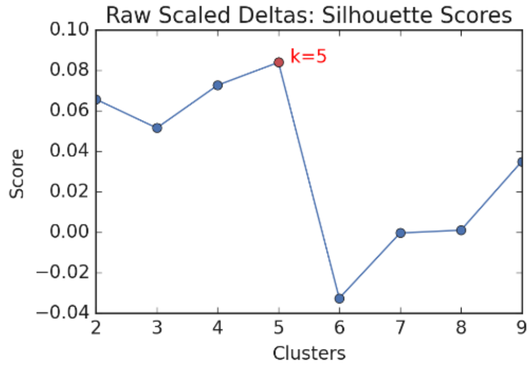
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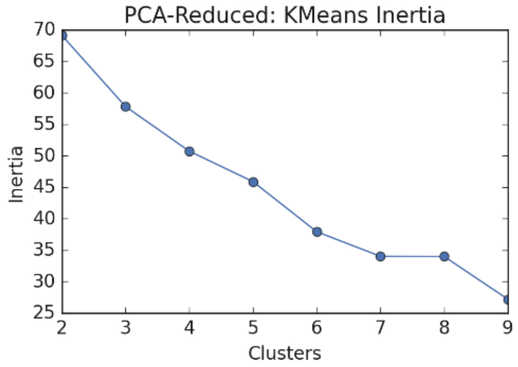
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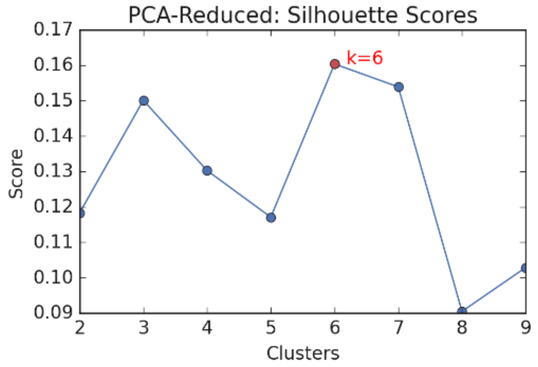
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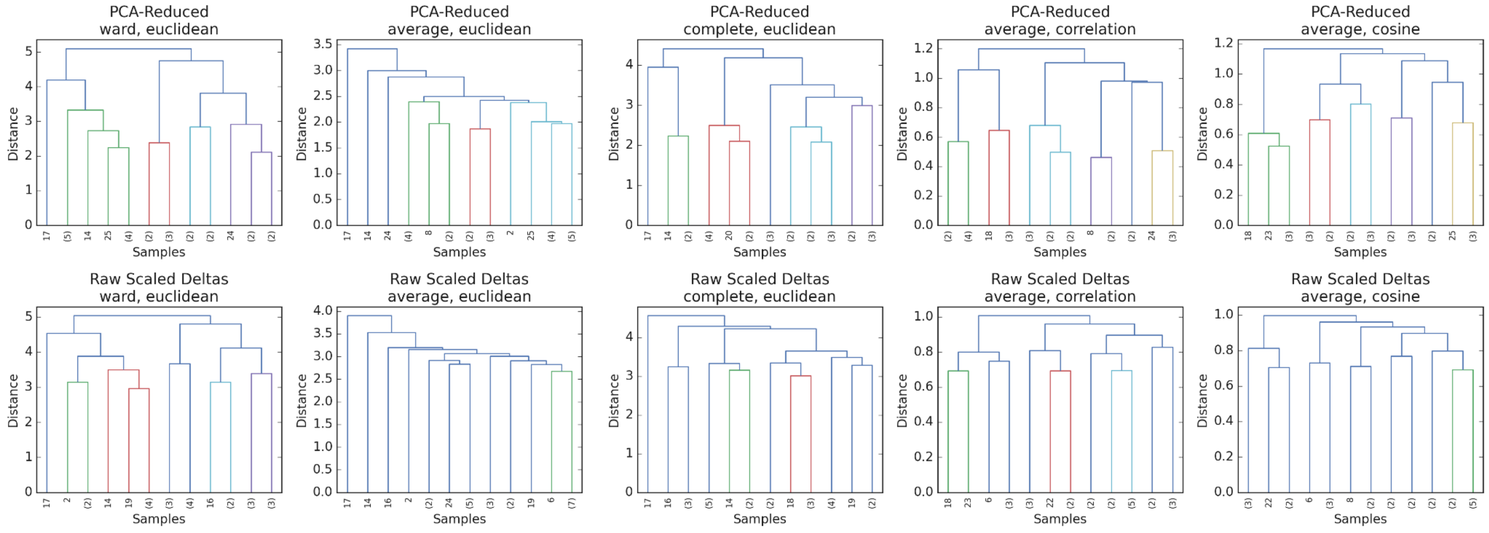
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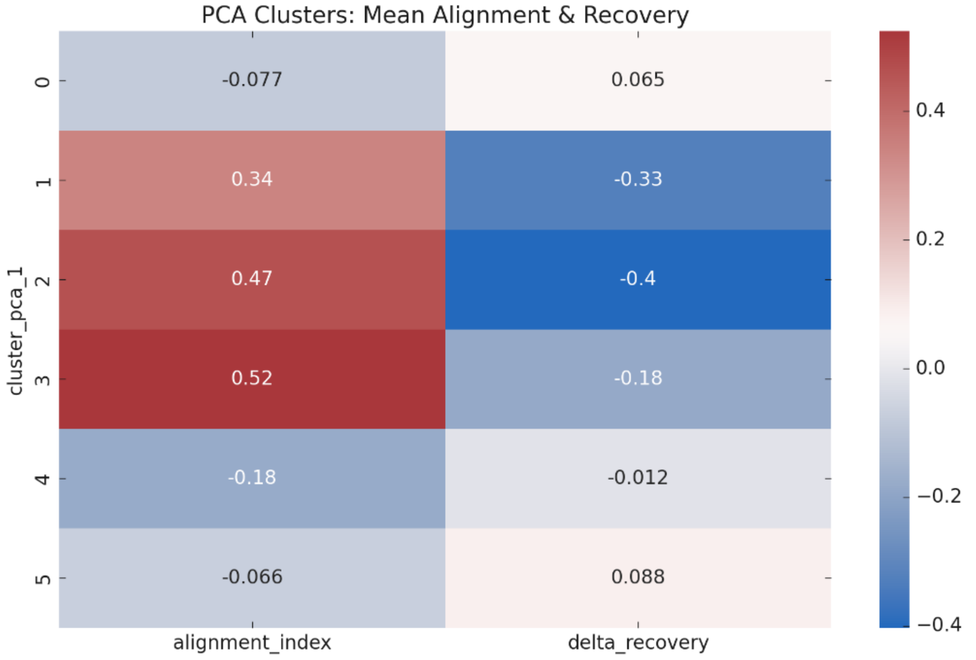
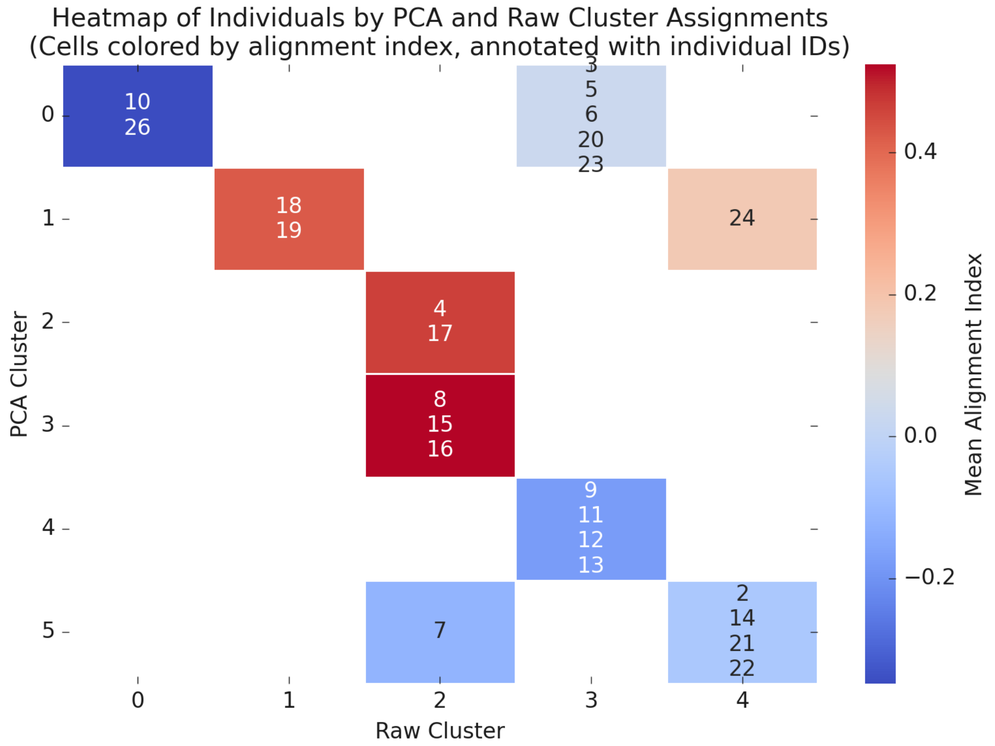
K-means Cluster profiles

- Six distinct physiological-emotional response clusters were identified
- Key patterns ranged from high reactivity and alignment to low reactivity and negative alignment
- Smaller clusters showed more variability but clearer response signatures
- Recovery patterns varied: some clusters showed declining adaptation, others remained stable
- Hierarchical clustering confirmed these groupings, supporting the robustness of findings

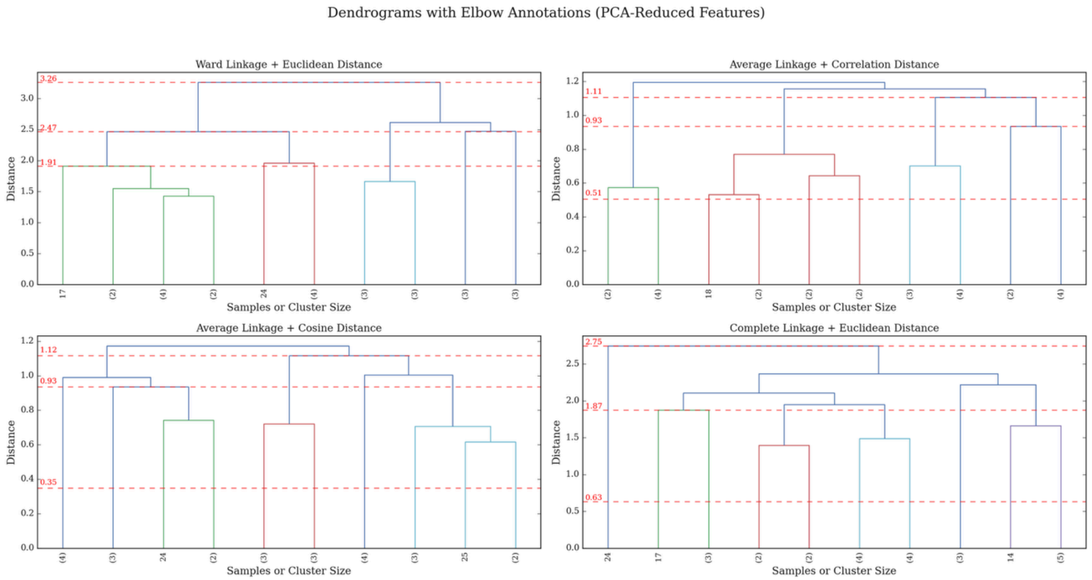


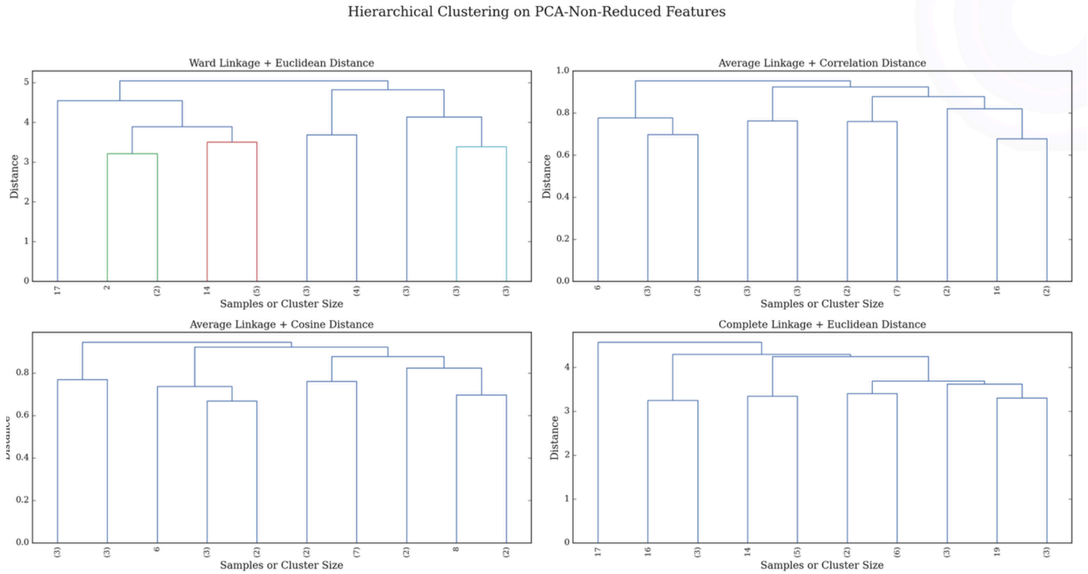
Comparison

- Compared results from PCA-reduced and raw data clustering
- Heatmap shows high agreement in participant groupings across methods
- Consistent patterns suggest robust, reliable physiological-emotional profiles
- Findings are not artifacts of the clustering technique but reflect genuine response types



Hierarchical Structure Considerations

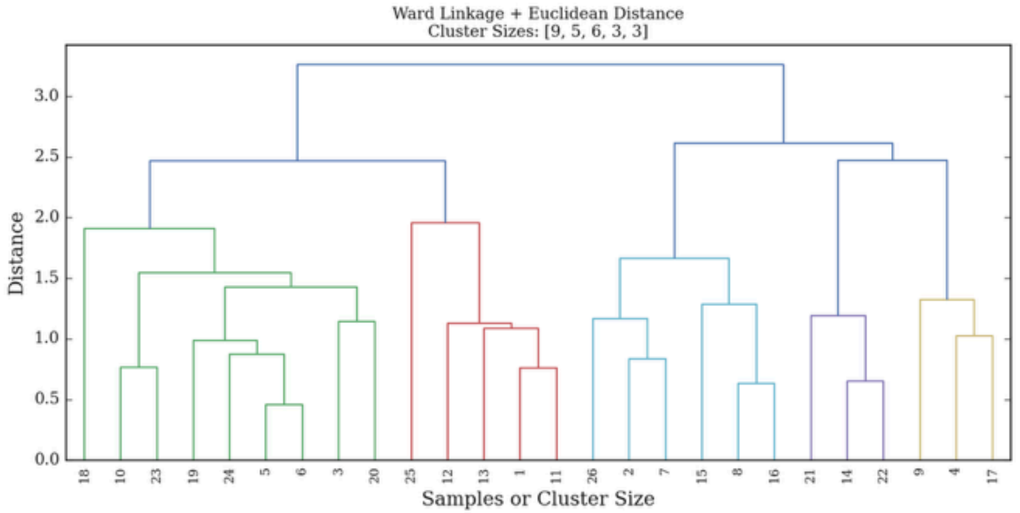


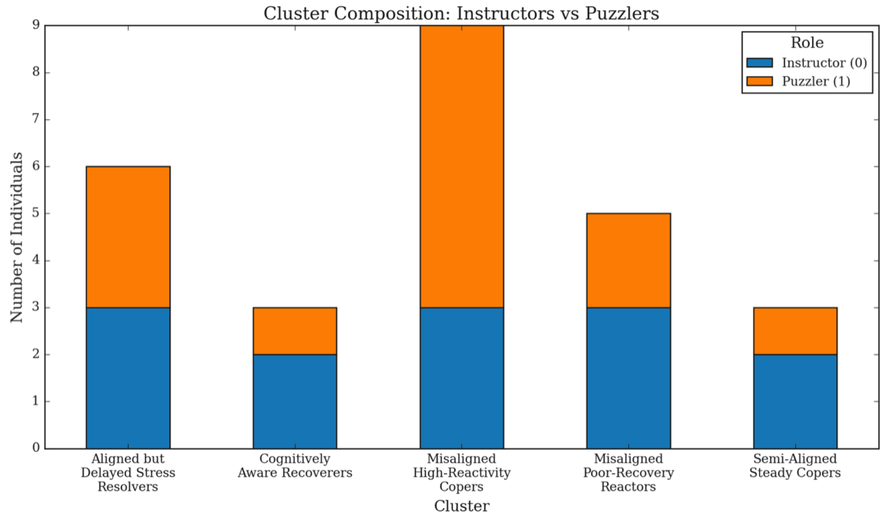


Aspect	PCA reduced	Data without dim. reduction
Input Features	PCA of deltas	All scaled deltas (raw)
Visual Complexity	High (rich branching)	Lower (symmetrical structure)
Clarity of Groups	Higher	Moderate
Clustering Interpretability	Richer psychological **context**	Stronger physiological **focus**
Best Use Case	Insight into individual alignment	Objective pattern recognition

Final Model

- Ward Linkage + Euclidean Distance, 5 cluster Hierarchical Clustering on PCA reduced delta features





Cluster	Label	Alignment	Recovery	EDA Pattern
1	Misaligned High-Reactivity Copers (green)	Slightly neg	Stable → ↑	Mild load
2	Misaligned Poor-Recovery Reactors (red)	Strongly neg	↓↓↓	Accumulative stress
3	Aligned but Delayed Stress Resolvers (blue)	Strongly pos	↓ by R4	Dip then spike
4	Semi-Aligned Steady Copers (purple)	Moderate pos	Gradual ↑	Flat/moderate
5	Cognitively Aware Recoverers (yellow)	Moderate pos	Clear ↑ by R4	Mild up → down

Discussion

- *“Do distinct physiological-emotional response patterns exist among participants during competitive puzzle-solving tasks, and what characterizes these different profiles?”*

- **Yes**, distinct physiological-emotional response patterns were identified during competitive puzzle-solving tasks

- Six clusters emerged, each with unique profiles of physiological reactivity, emotional alignment, and recovery trajectories

- Cross-method consistency confirms robustness of findings