Head Movement Patterns during Face-to-Face Conversations Vary with Age

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Head Movements for Behavioral Analysis

- Significant for Social Communication
  - Fundamental aspect of non-verbal communication
  - Taxonomy of head movement[1]
    - Linguistic meaning, referencing space, controlling interpersonal interaction
  - Information about characteristics of interaction partners
    - Mental and emotional characteristics
    - Cognitive states

[1] Evelyn Z McClave. 2000. Linguistic functions of head movements in the context of speech. Journal of pragmatics 32, 7 (2000), 855–878.

Head Movements for Behavioral Analysis

- Head Movement and Social Communication Across Development
  - Infancy and toddlerhood.
    - Fairly well-understood relationship
      - Object tracking, social orienting and referencing,
    - Infant-mother emotional interaction
  - Older children and adolescents
    - Less well-studied relationship
    - Non-social head movement in response to visual stimuli in children 4-15 years
      - Frequency and variability of head movement decrease with age
      - Children engage the head less during gaze shifts as they age

Head Movements for Behavioral Analysis

- Computational Analysis of Head Movement
  - Relies on advances in computer vision and machine learning
  - Application Areas
    - Screen-based tasks, human-robot interaction
  - Recently, used to understand mental health and neurodevelopmental conditions
    - Autistic children shown to exhibit differences in head movement dynamics relative to their neurotypical peers

Contributions

- Monadic and dyadic analysis to better capture broader social context of head movement
- Computationally modeling patterns of head movements during conversation rather than overall kinematic features
- Quantification of the extent to which head movements are shaped by development

Methods: Participants

Table 1: Sample characterization by age group

Age Group	n	Age (years) Min-Max	Sex F:M	Full Scale IQ Mean (Std)
≤ 12	39	$5 - 12$	18:21	111.6(13.8)
> 12	40	$12 - 48$	11:29	109.6(11.0)
Total	79	$5 - 48$	29:50	110.6(12.4)

Methods: Experimental Procedure

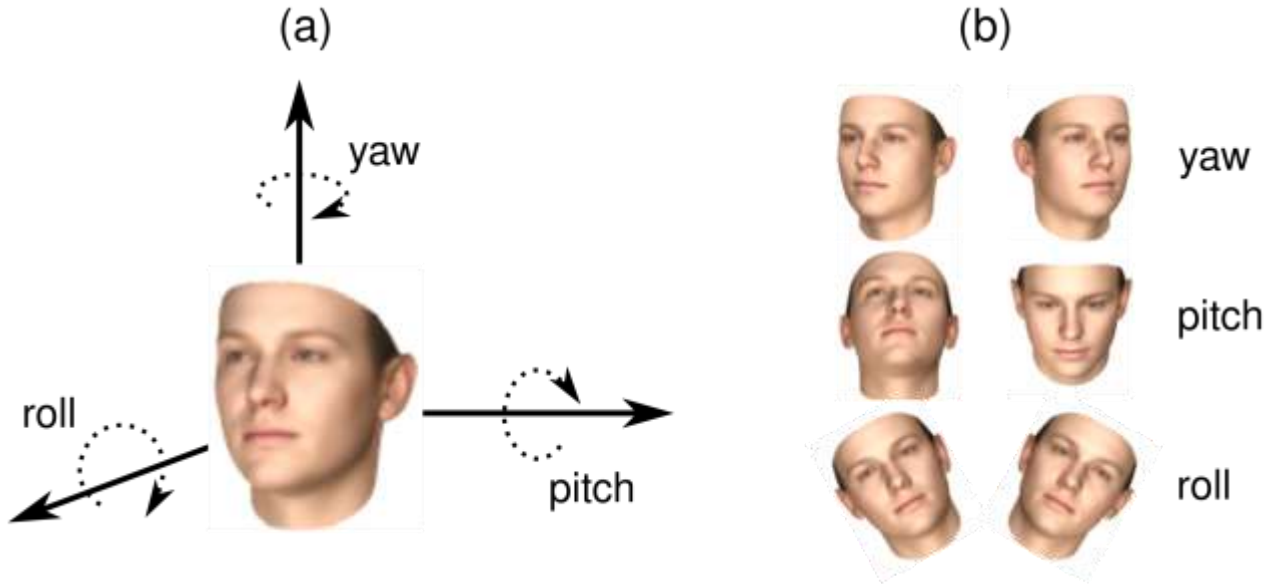
- Battery of tasks: a modified version of the Contextual Assessment of Social Skills (CASS)
  - Semi–structured assessment of conversational ability designed to mimic real–life first–time encounters.
  - 3-minute face-to-face conversation between participant and confederate
  - Confederates were trained to speak for no more than 50% of the time and to wait 10s to initiate the conversation.

Methods: Data Collection

- Continuous audio and video of the 3–minute CASS recorded using a specialized "BioSensor"
- Two HD cameras pointing in opposite directions and two microphones
- Simultaneous recording
- Minimal device footprint and intrusiveness

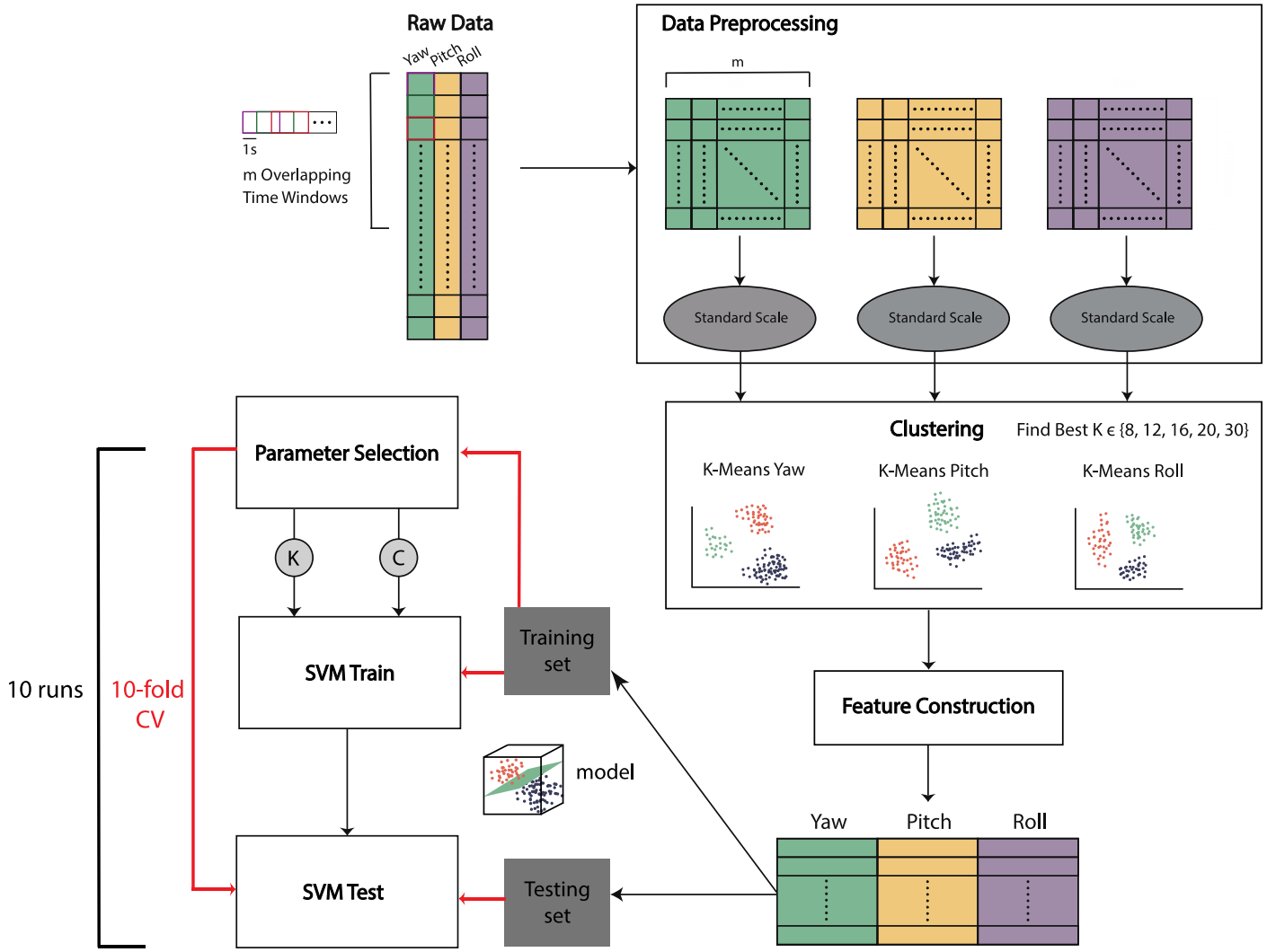
Methods: Data Pre-Processing

- First and last 3 seconds trimmed
- Rate of 30 fps
- 3D face modeling
  - 3 time-dependent signals extracted: *yaw*, *pitch*, and *roll* head angles



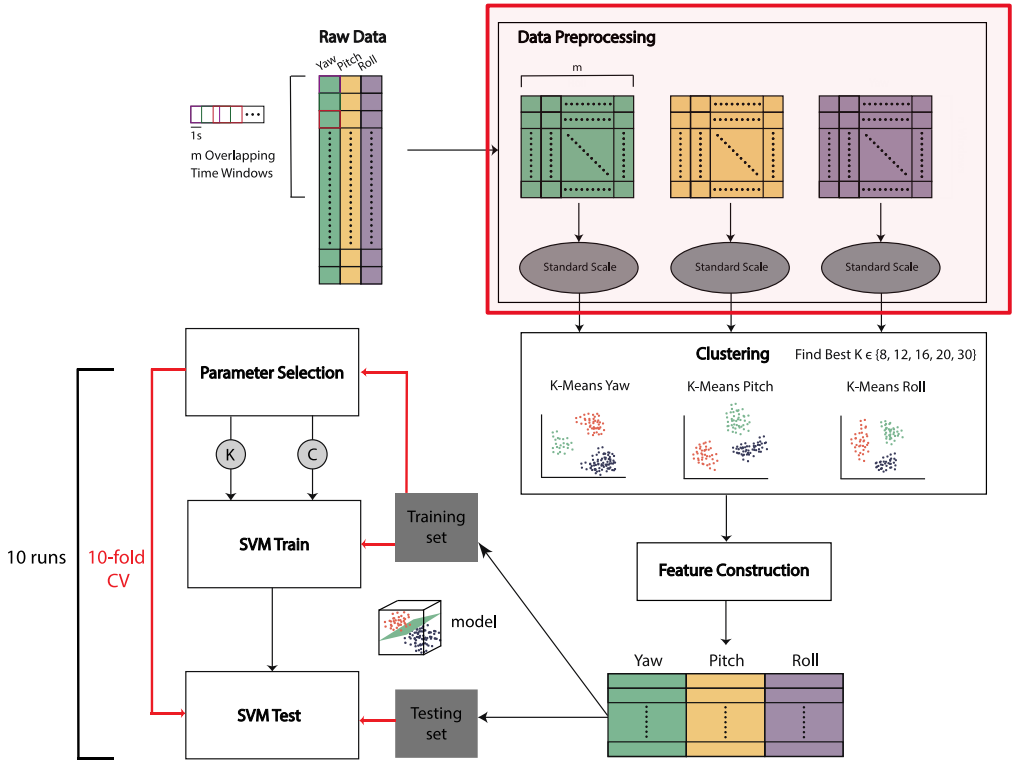
Methods: Analysis Overview

- Raw Data
- Data Processing
- Clustering
- Feature Construction
- Training and Evaluation
  - Parameter Selection
  - Classification



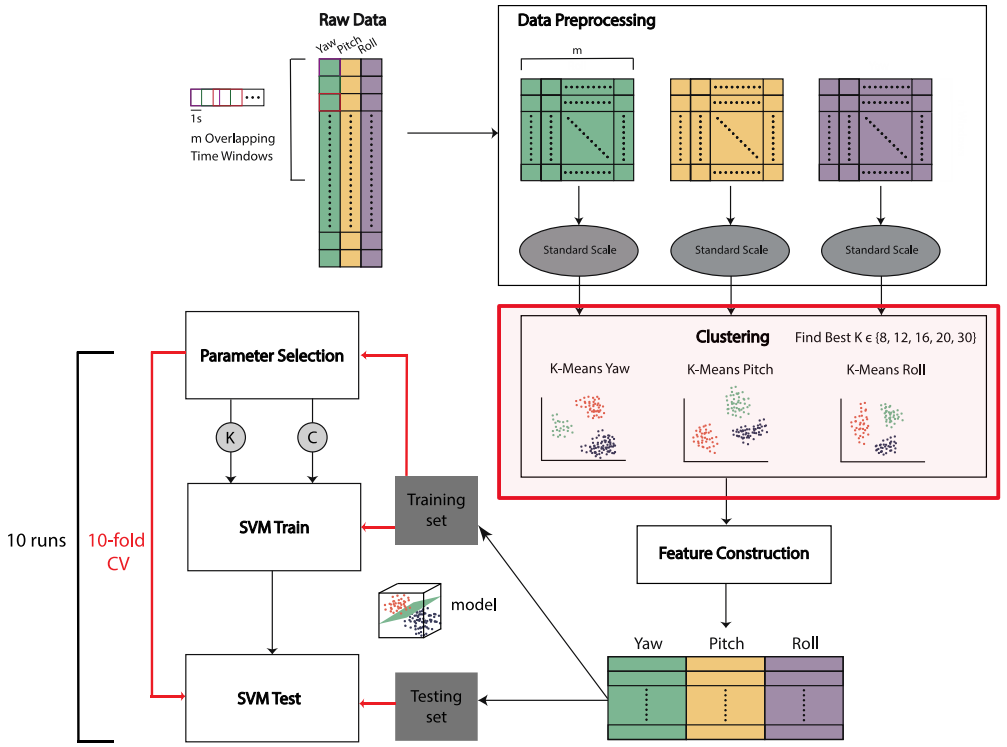
Methods: Data Processing

- For each participant
  - 4-second time windows with overlap
  - Each window standardized (mean = 0, std dev = 1)
- 52,692 total time windows from all participants used for clustering



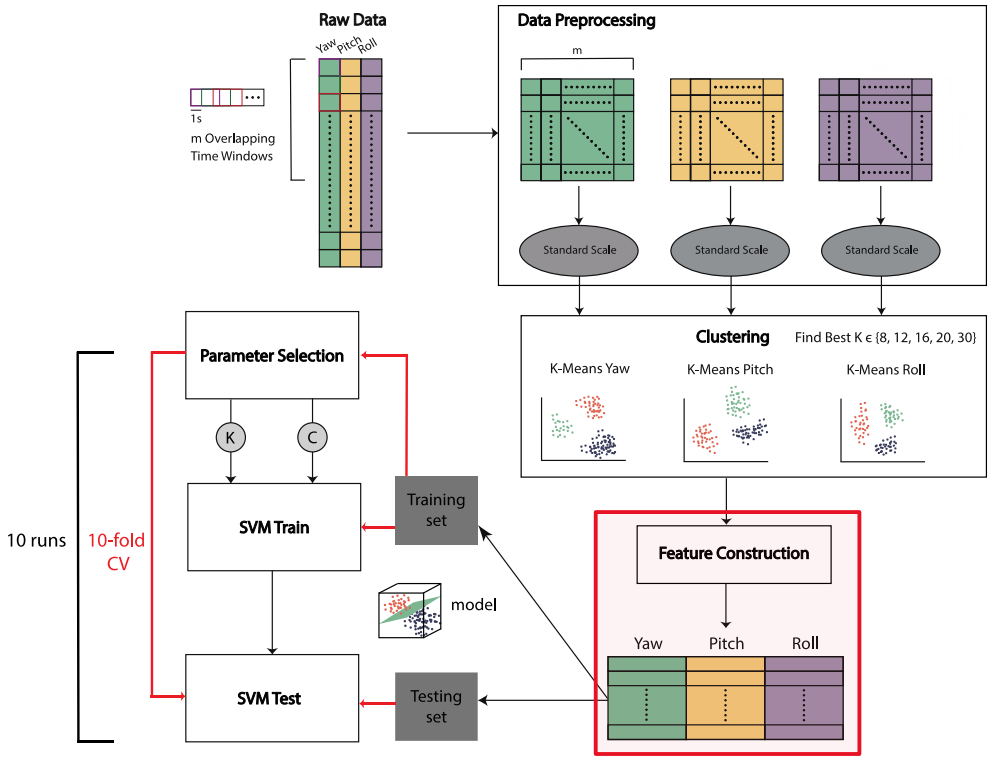
Methods: K-Means Clustering

- *K-Means* clustering to group head movement snapshots by similarity
- Select *K* using cross-validation
- Three separate K-Means models: *roll*, *pitch*, and *yaw*

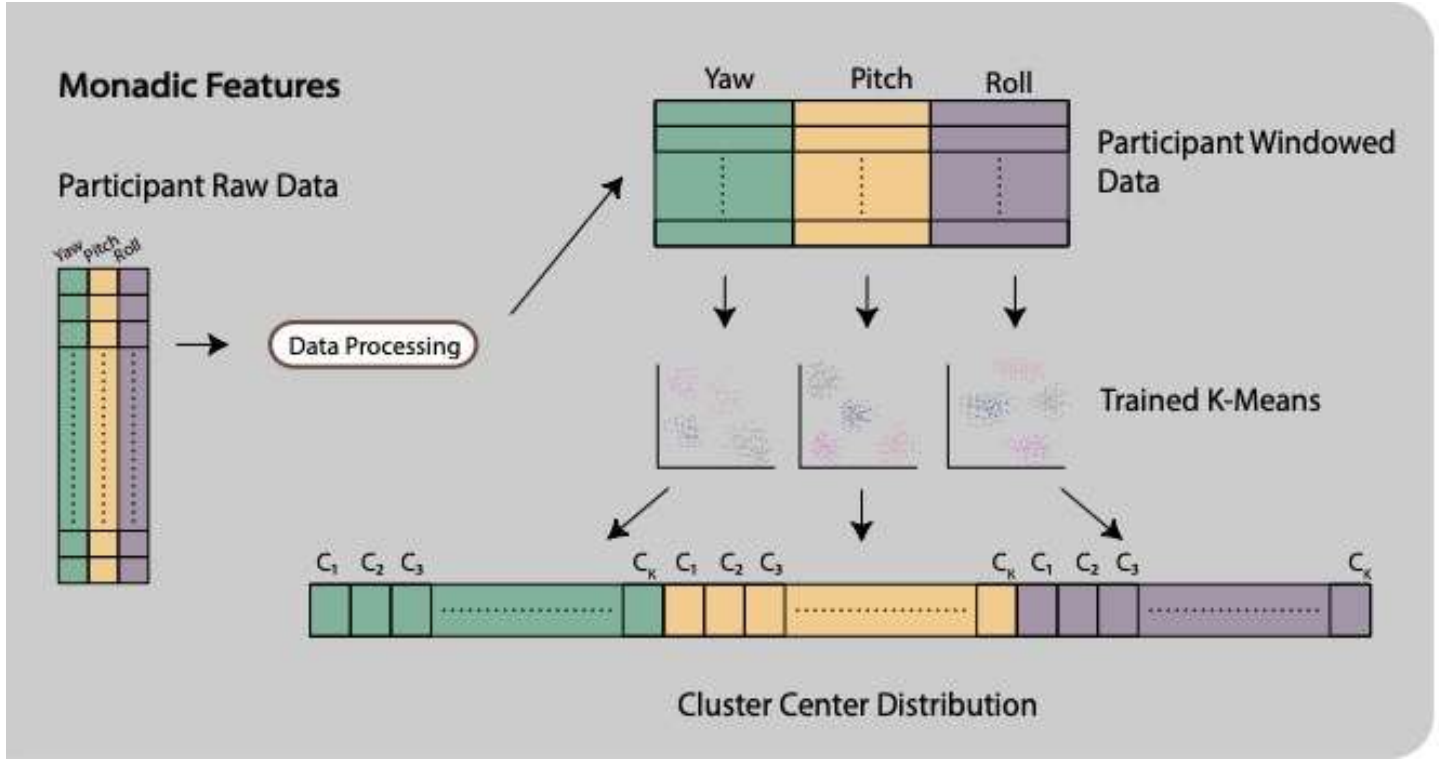


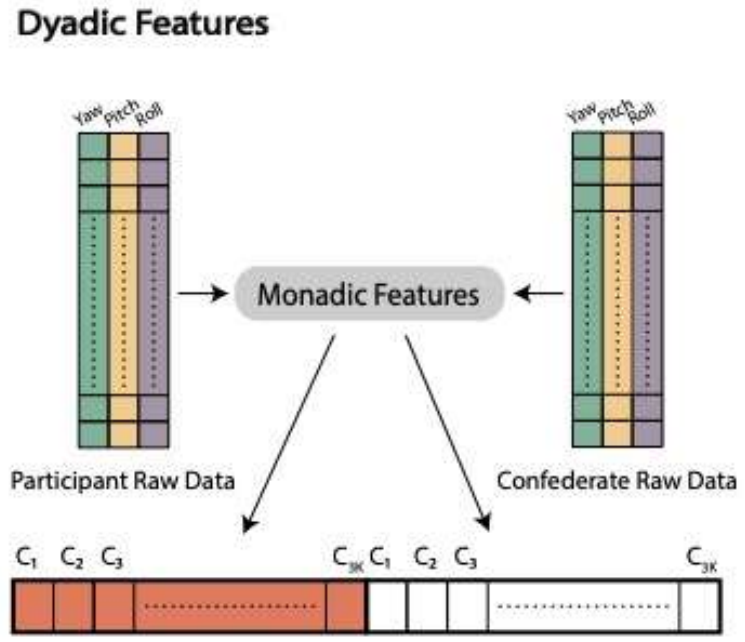
Methods: Feature Construction

- Essence: for each participant count the number of times they exhibit certain head movement patterns based on trained K-Means clusters
- *Monadic* case: only participant data used
- *Dyadic* case: participant and confederate data used to provide context



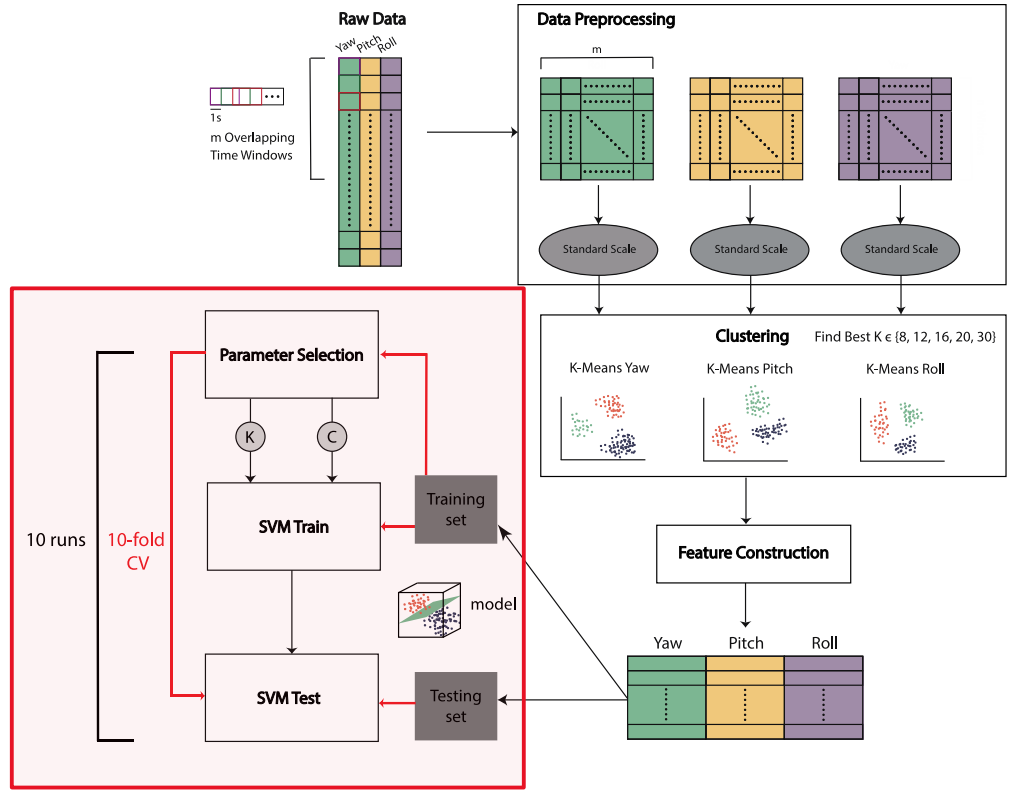
Methods: Feature Construction





Methods: Classification

- Classification
  - SVM classifier with linear kernel: age below or above 12
  - 10 times 10-fold cross-validation for statistical robustness
  - Best *K* value stored for regression and feature selection
- Parameter Selection
  - Inner 5-fold cross-validation
  - Best *K* (for K-Means) and *C* (for SVM)



Methods: Regression

- Predicting a continuous value for age
- Nested cross-validation
- Fixed *K* and *C*
- Optimized kernel choice (linear vs rbf)

Methods: Relevant Features

- Features that contributed most strongly to classification accuracy
  - Fix K and other classification parameters
  - Re-cluster data
  - Run SVM classification using all data
  - Extract feature coefficients corresponding to feature importance
  - Visualize pattern of head movement
    - Monadic
    - Dyadic

Results: Classification

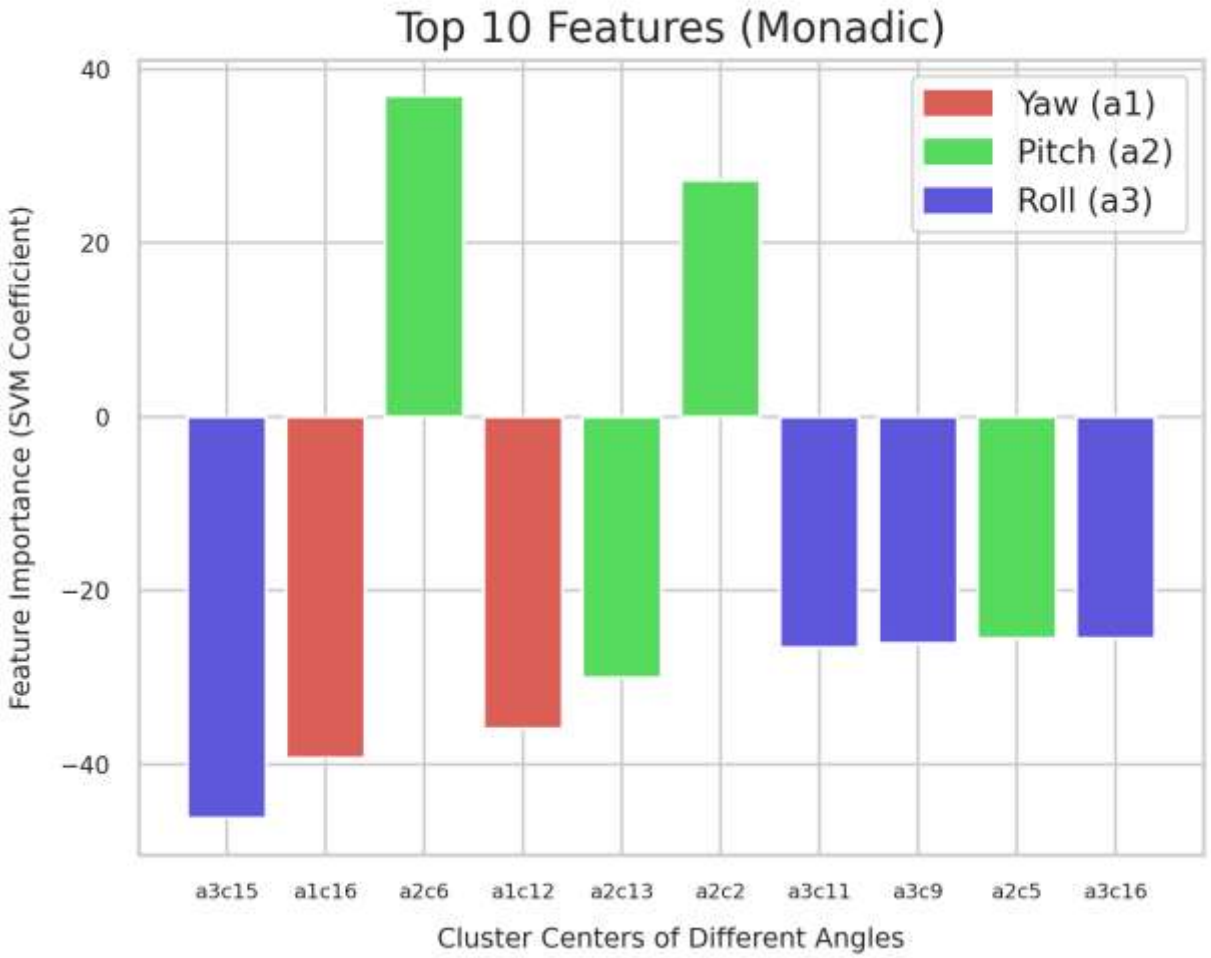
Table 2: Classification results for both *monadic* and *dyadic* features. The reported scores are means of the 10 experimental runs and balanced across the two classes.

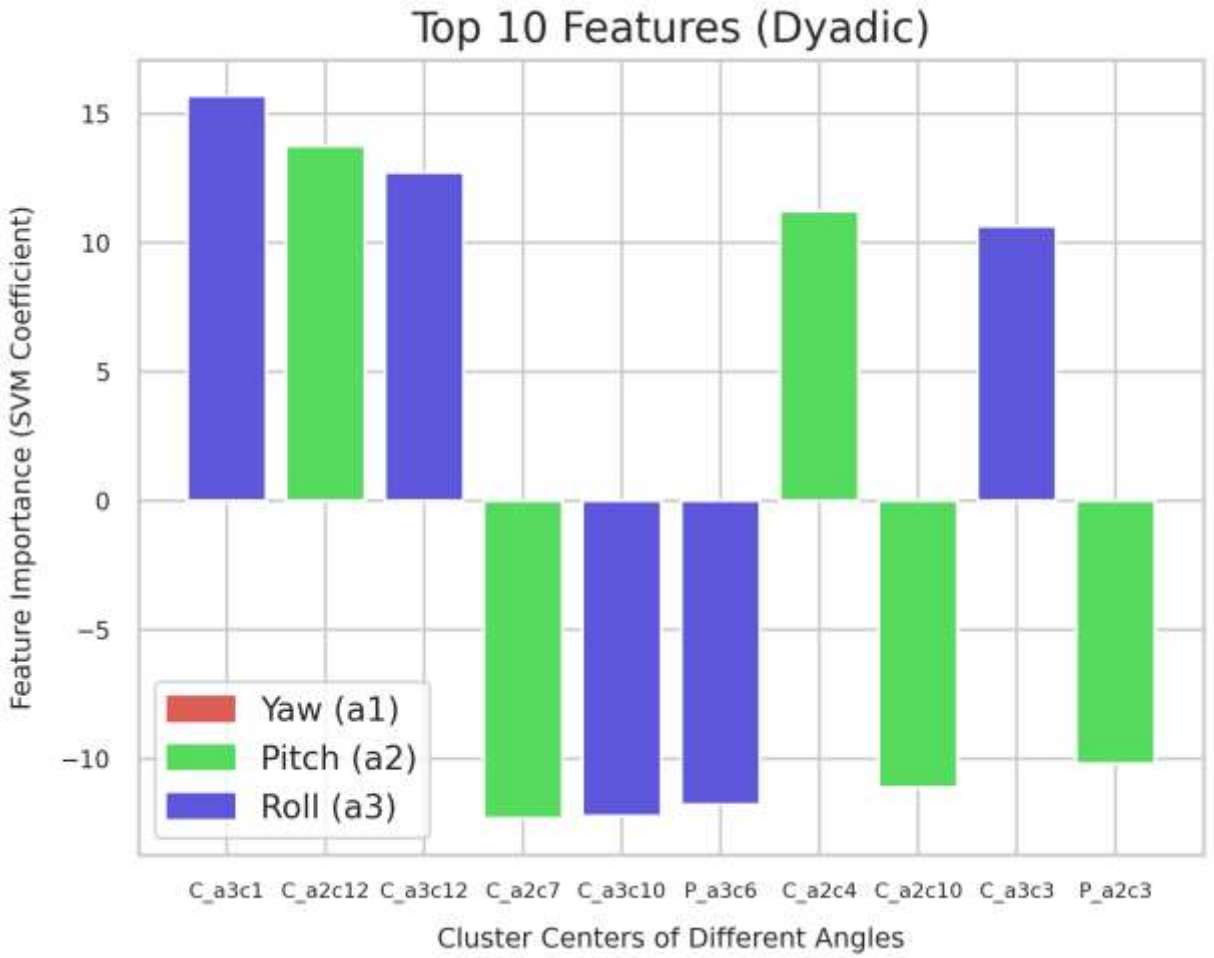
	Accuracy	F1–Score	Precision	Recall	ROC (AUC)
Monadic	71.4%	71.4%	71.5%	71.4%	71.4%
Dyadic	78.6%	78.6%	78.7%	78.6%	78.6%

Results: Regression

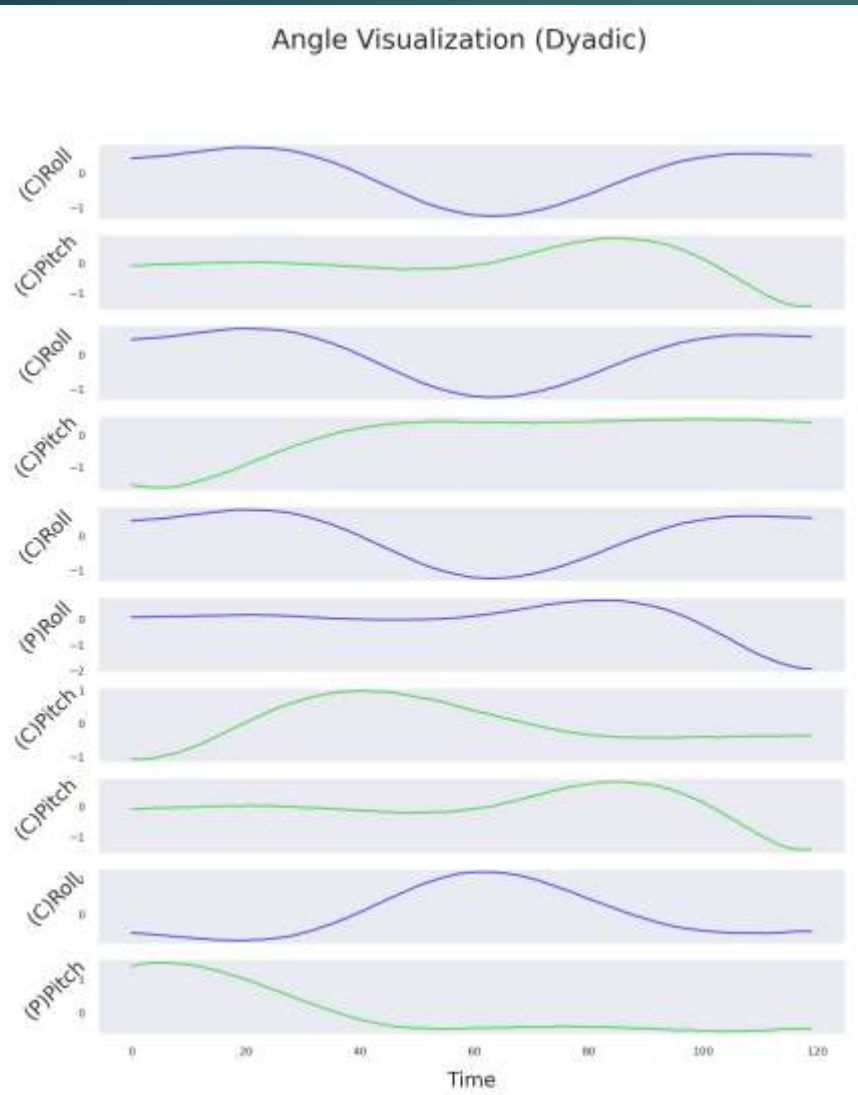
- Chronological age and predicted age
- Used best performing features from classification (*dyadic* case)
- Pearson correlation (r) = 0.42, p = 0.0001

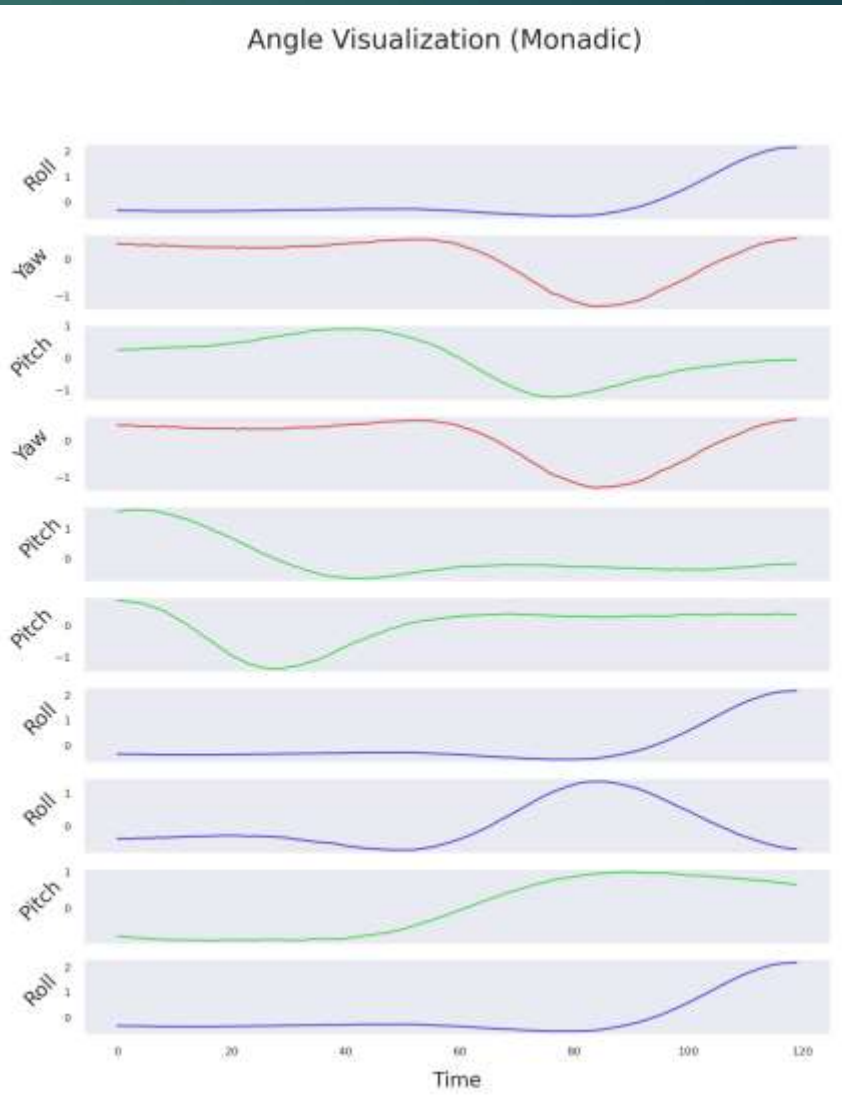
Results: Relevant Features





Results: Relevant Features





Discussion

- This work provides measures to quantify extent to which head movement changes with age.
- Possible to distinguish between individuals younger versus older than 12 years based on their head movement patterns during a 3–minute, casual, face–to–face conversation.
- Head movements capable of accurately predicting age continuously (sample range 5.5-48 years)
- *Dyadic* approach achieved higher accuracy than the *monadic approach*

Future Work

- Dyadic features capturing coordination between participant and confederate
- Joint head angle representation
- Meaningful event detection
- Generalizability of these results

Summary

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- Computational methods to extract meaningful information from head movement patterns.

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