Combining Biclustering with Probabilistic Predictive Models to Develop Personalised Tests for **Early Detection of Dementia**

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Introduction and background

- Dementia is a significant health challenge for the elderly population.
- Early detection of dementia is difficult and lacks appropriate diagnostic tools ⟶ an accessible tool for tracking memory condition needed
- The Famous Faces Test (FFT) is a potential tool for dementia detection. It involves naming photos of famous people and recalling their names or selecting from a list.
- This research aims to introduce **personalisation to the FFT** using data science.

Example prompt for the *recall task*

Example prompt for the *recognition task*

Methods

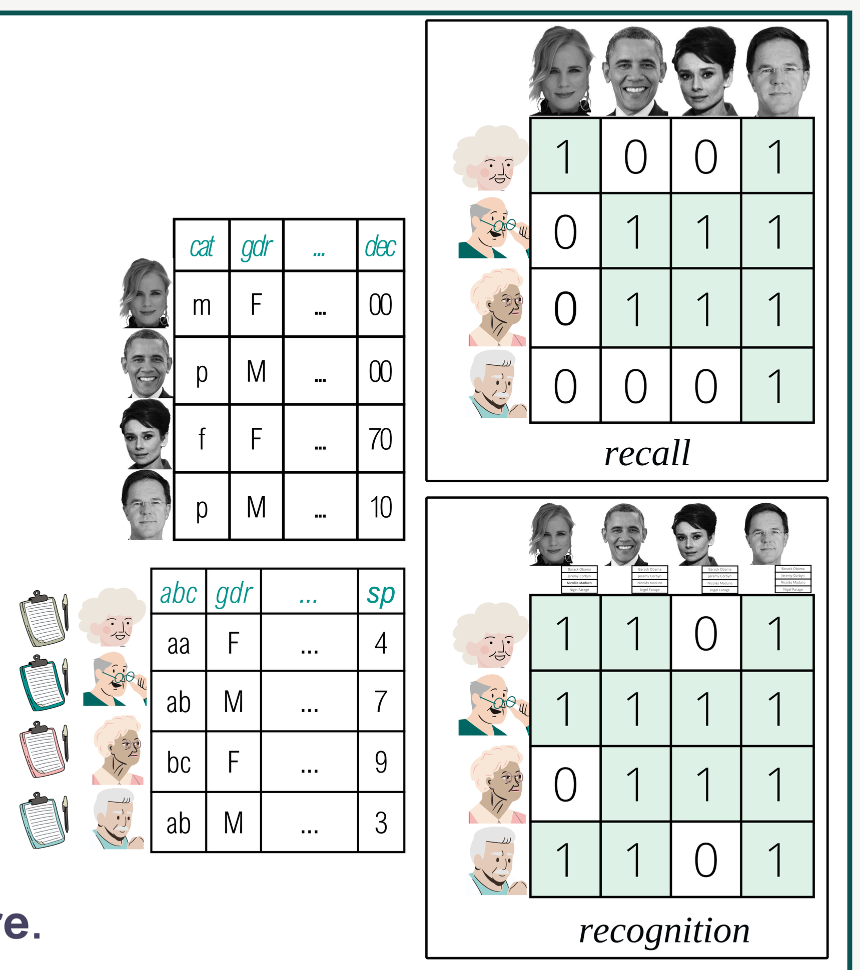
- **Data**: FFT results on recall and recognition tasks of over 300 individuals, information about the participants, collected via questionnaires, and the test items [1]
- **Population**: cognitively normal Dutch adults aged ⩾60

Individual differences and biclustering

- **Information-Theoretic Co-Clustering** - comparing 2 sets of features, based on mutual information [2,3].

Modelling

- Aim: generate a personalised set of *n* faces based on patient characteristics.
- 3 probabilistic classifiers compared: **Logistic Regression, SVM, Gaussian Naïve Bayes**.
- Comparison in two settings: with and without **bicluster membership as an additional feature**.
- **Multi-label classification** using separate binary models per face.
- Optimal items derived by aggregating models and selecting items with probability scores around some threshold.

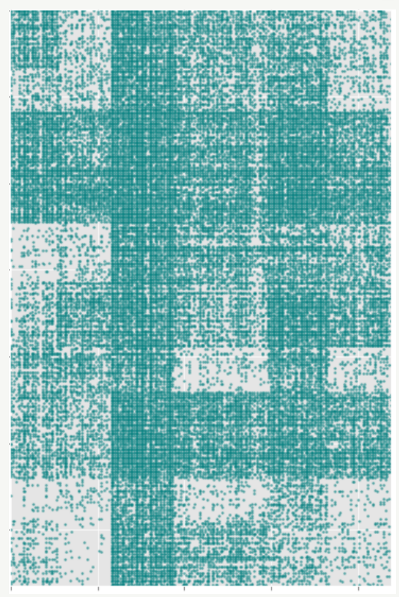


A schematic representation of the structure of the data used in this research.

Data

Biclustering

- Information-Theoretic Co-Clustering
- feature selection for interpreting clusters



The rearranged matrix showing the discovered structure.

Model

- probabilistic classifiers
- multi-label classification
- bicluster as feature

evaluation

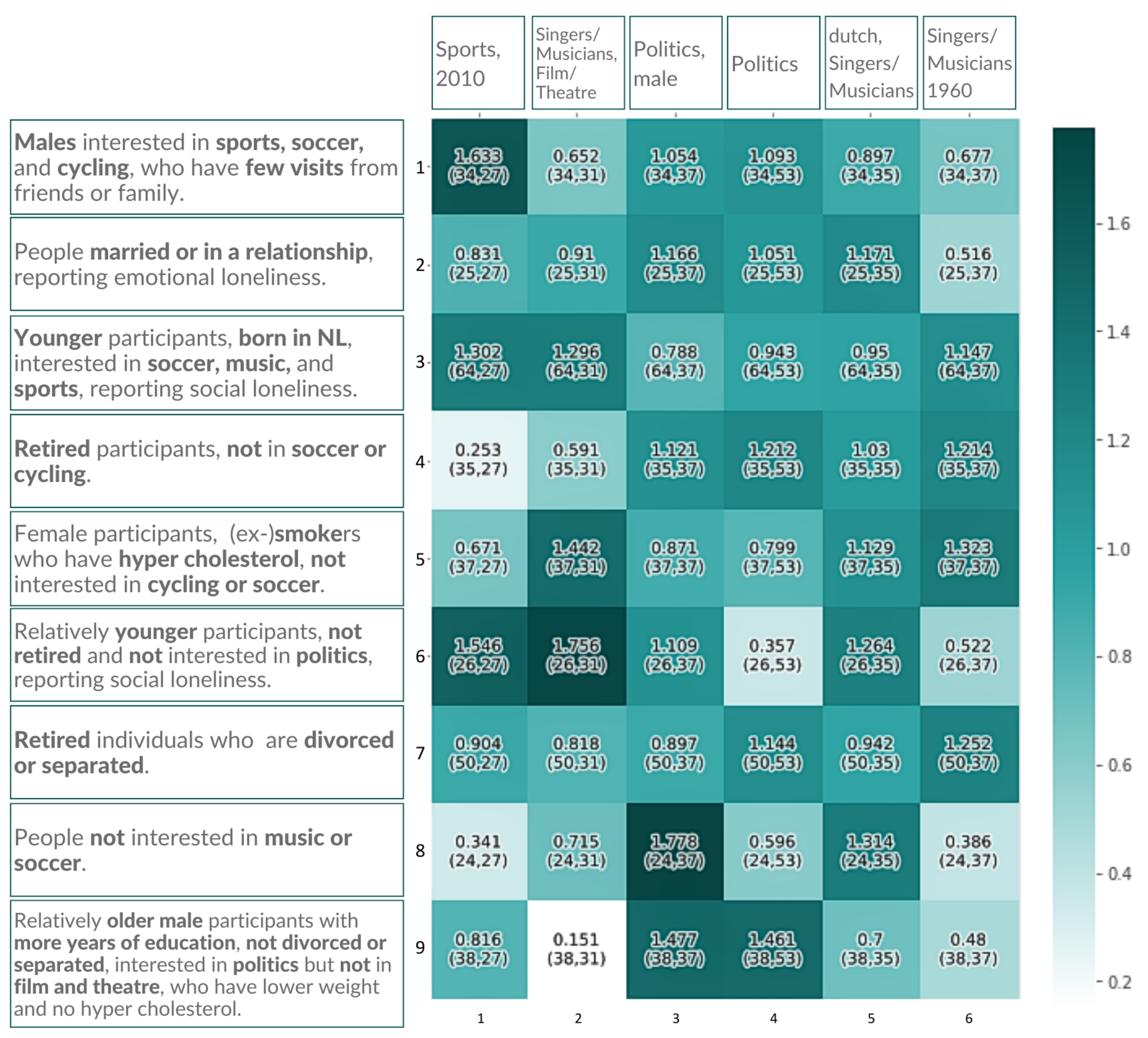
Logistic regression consistently outperformed all the other models.

Bicluster membership as an additional feature had a consistently positive impact on the classifiers' performance.

Best model:
Logistic Regression with bicluster membership information

Accuracy: 70% F1-score: 0.57

Are there individual differences in the FFT performance?



Cluster informativeness (mutual information score δ_{kl}) graph with descriptions derived with feature selection. A darker shade corresponds to a bicluster having more correct answers.

- Evidence of **individual differences in FFT recall task** performance.
- Participants and items tend to form groups.
- Visualisation of **cluster informativeness** with correlated features (**feature selection**).
- Existence of meaningful biclusters indicates individual differences.

How can a test set adapted to an individual be generated?

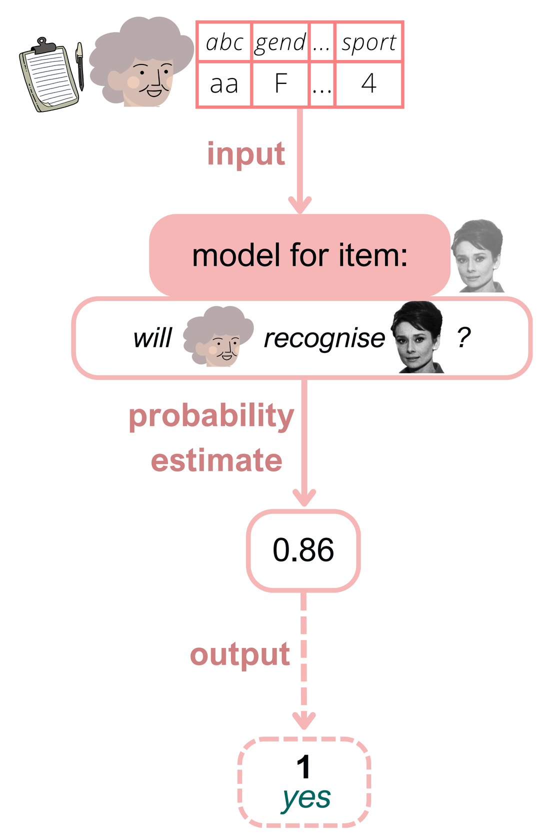


Diagram of a single model

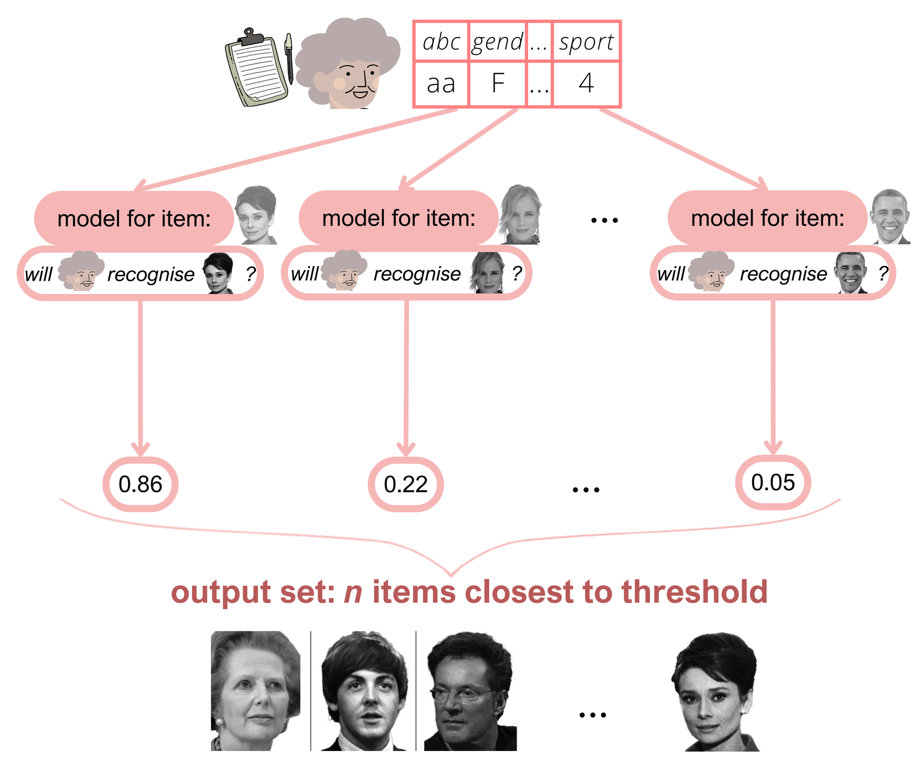
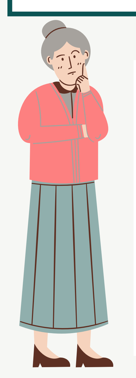


Diagram of an aggregated model system

- **Logistic regression** consistently outperformed the other candidate models.
- Bicluster information had a modest but **positive effect on results**, increasing accuracy by an average of 2.8 percentage points.
- The results and performance metrics should be viewed through the prism of the application - for example, at 10 faces, accuracy is around 90% for recall.



Model "in action"

- An example prediction of a set of 10 faces that a person is the most likely to name correctly.
- Participant (from the test set): a 65-year-old woman, interested in music and, moderately, politics, but not in soccer or cycling.
- Output: 10 faces - in reality, she indeed recalled all of their names correctly.

Limitations

- Small sample size.
- Data from a specific population.
- Need for further verification in different countries.
- Crucial next steps: testing on early stage dementia patients, consultation with experts and practitioners.

Conclusion and practical implications

- There are individual differences in FFT performance and **individualised FFT sets** can be generated.
- Adaptive tools for early dementia detection with **adjustable difficulty** and **interest matching** on the individual level can benefit patients and practitioners.
- Biclustering visualisation and probability estimates enhance the solution's **interpretability**.
- Adding bicluster membership information can improve classification results of probabilistic classifiers.

References

[1] van den Elzen, E. H. T., Brehmer, Y., Van Deun, K., & Mark, R. E. (2023). Stimulus material selection for the Dutch famous faces test for older adults. Frontiers in Medicine, 10. https://doi.org/10.3389/FMED.2023.1124986
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[3] Role, F., Morbieu, S., & Nadif, M. (2019). CoClust: A Python Package for Co-Clustering. *Journal of Statistical Software*, *88*(7). https://doi.org/10.18637/jss.v088.i07

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