EMHMM: Eye Movement Analysis with Hidden Markov Models

Lecture 3

Janet H. Hsiao
Dept. of Psychology,
The University of Hong Kong

Antoni B. Chan
Dept. of Computer Science
City University of Hong Kong

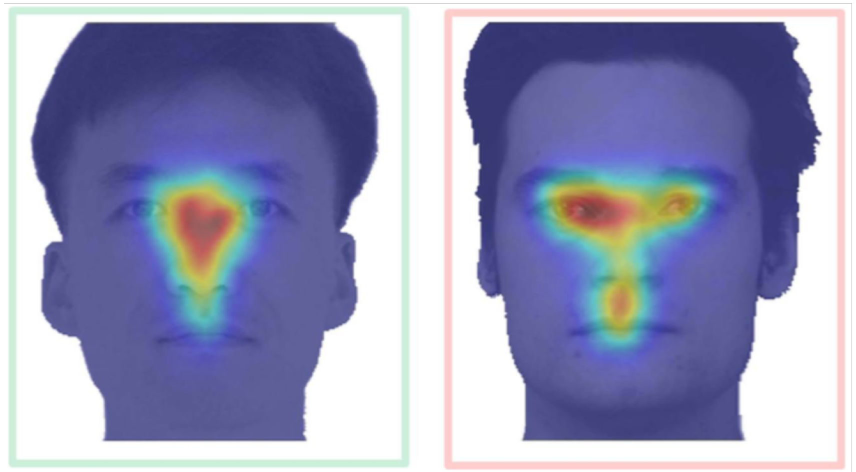
Outline

- **Introduction to EMHMM with co-clustering**
  - Scene perception
- Project development: data collection and data analysis

Hsiao, J. H., Chan, K. Y., Du, Y. & Chan, A. B. (2019). Understanding individual differences in eye movement pattern during scene perception through hidden Markov modeling. *Proceeding of the 41th Annual Conference of the Cognitive Science Society*. Austin, TX: Cognitive Science Society.

Background

- Cultural difference in analytic vs. holistic perception style has been demonstrated in eye movements
  - Scene perception: Westerners looked at foreground objects (analytic) whereas Asians looked at backgrounds (holistic) more often (Chua, Boland, & Nisbett, 2005).
  - Face recognition: Westerners looked at facial features (analytic) whereas Asians looked at the face centre (holistic; Blais et al., 2008).



Face recognition (Kelly et al., 2011)

Background

- Through **EMHMM** (Chuk et al., 2014), Chuk et al. (2017) showed that analytic and holistic perception styles in face recognition were observed in both Asians and Caucasians.
- Analytic patterns were associated with better recognition performance whereas holistic patterns were associated with cognitive decline in executive function and visual attention among older adults (Chan et al., 2018).

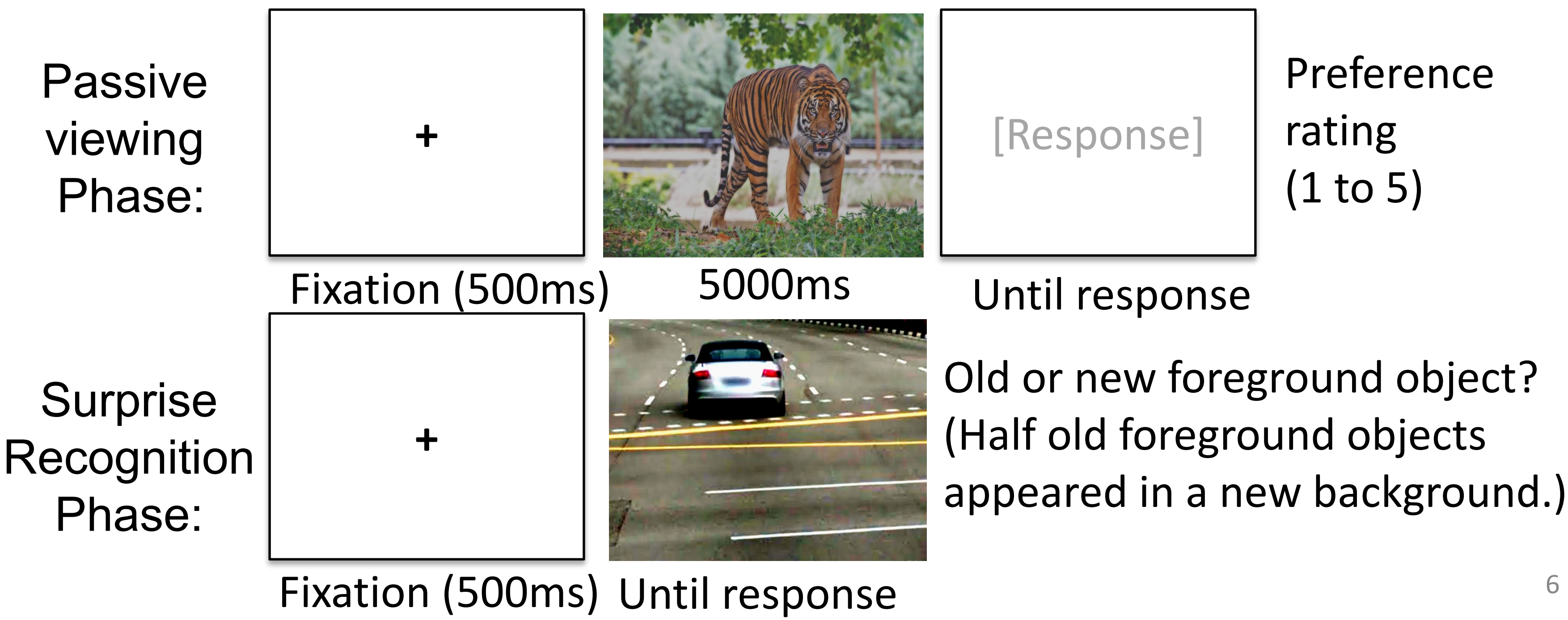
- Here we used EMHMM with co-clustering to discover participant groups with consistent eye movement patterns across stimuli during scene perception, and examined their associations with foreground object recognition performance and cognitive abilities.

EMHMM with co-clustering

- **How to summarize a general eye movement strategy in tasks where stimuli's feature layouts differ significantly** (e.g., scene perception, visual search, reading etc.)?
- **EMHMM with co-clustering**: 1 stimulus 1 model; use co-clustering to discover participants using the same pattern across stimuli.

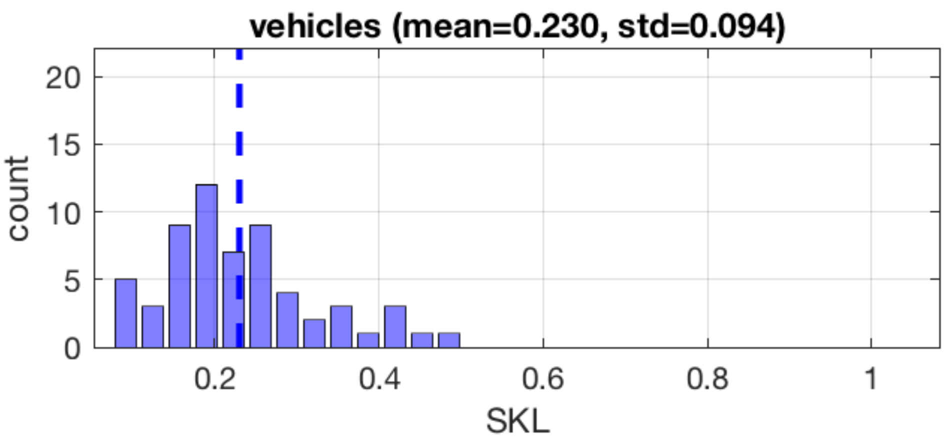
Experiment design

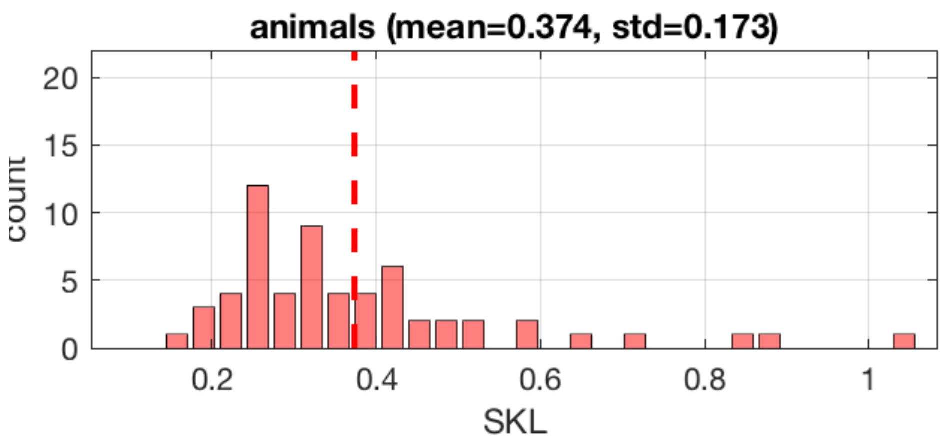
- **Participants & Materials:** 61 Asian participants (35 females) aged 18-25, viewed 60 animal images in a natural environment and 60 vehicle images in an urban environment.
- **Scene perception task procedure:**



EMHMM with co-clustering

- Participants' data across images are clustered into 2 groups using co-clustering, resulting in 2 group HMMs for each image.
- Histograms of Symmetric KL divergence (SKL) between the two general pattern groups on animal or vehicle images
  - SKL quantified the difference between the 2 group patterns for each stimulus.
  - Animal images induced larger differences than vehicle images.



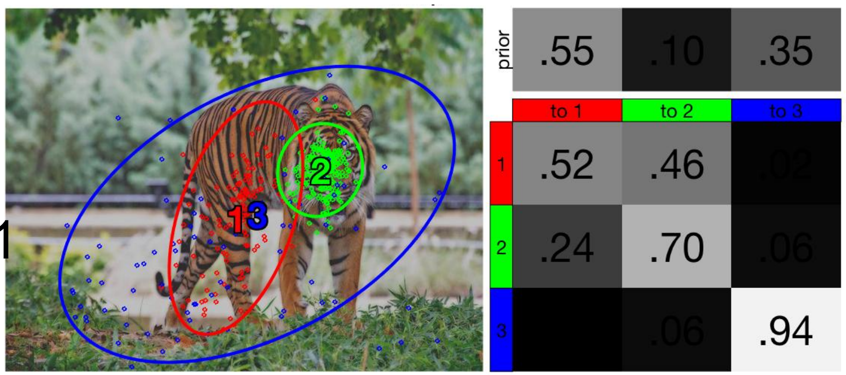


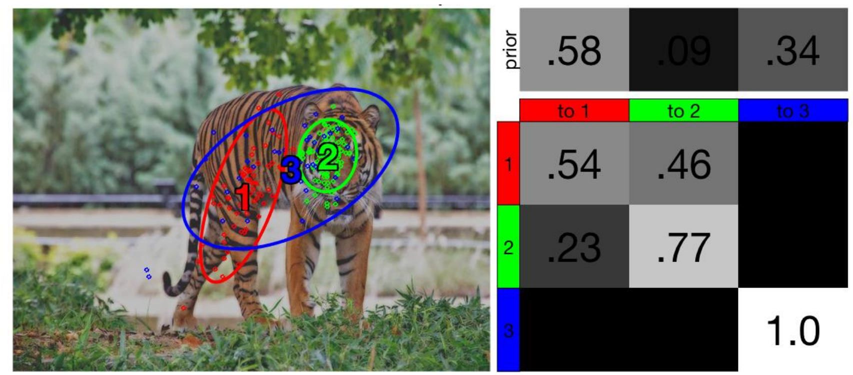
EMHMM with co-clustering: Results

Group 1: Explorative | **Group 2: Focused**

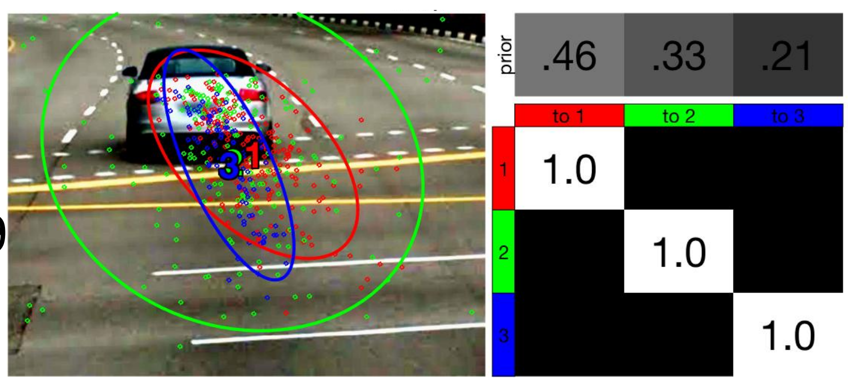
Large SKL Images

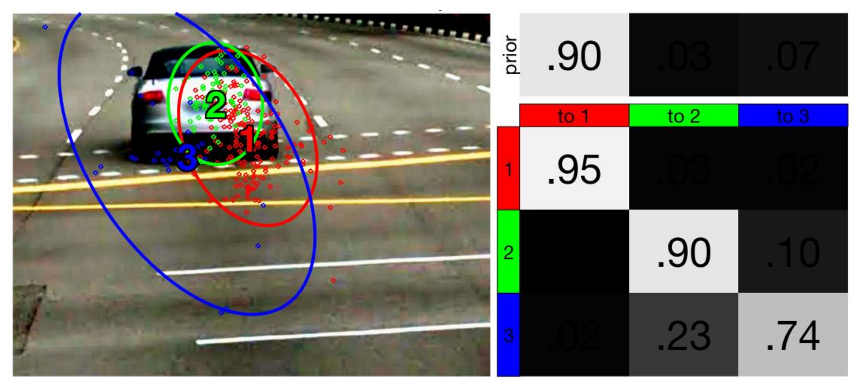
SKL 0.851





SKL 0.469



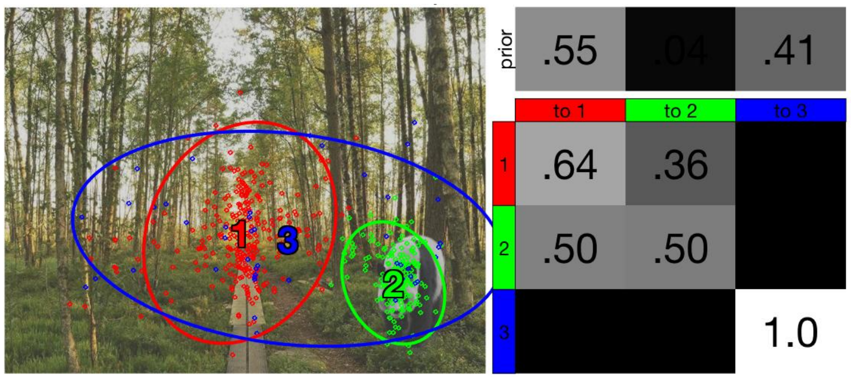


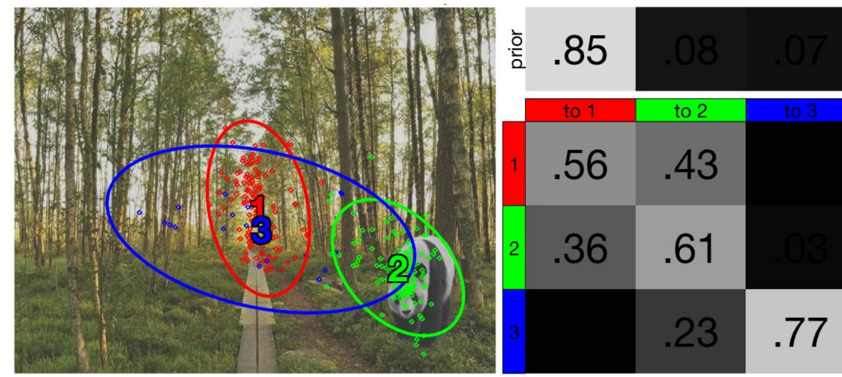
EMHMM with co-clustering: Results

Group 1: Explorative | **Group 2: Focused**

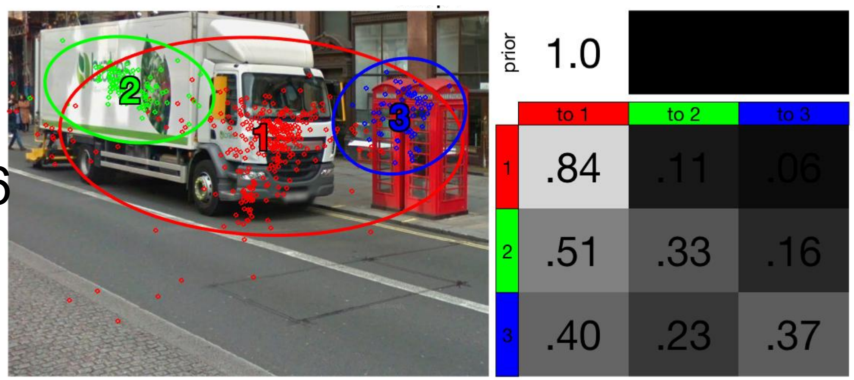
Small SKL Images

SKL
0.197





SKL
0.076



EMHMM with co-clustering: Results

Eye Movement differences between the two groups

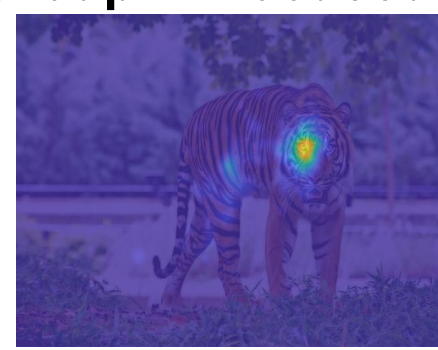
- The discovered two general patterns were significantly different from each other using KL divergence estimates:
  - Group 1 data log-likelihood was larger using Group 1 than Group 2 model, $p < .001$
  - Group 2 data log-likelihood was larger using Group 2 than Group 1 model, $p < .001$
- Participants using the Explorative pattern had <u>more fixations</u>, $p < .001$, <u>longer saccade lengths</u>, $p < .001$, and <u>lower preference ratings</u>, $p = .009$.

Group 1: Explorative

Look at animal eyes

Difference map

Group 2: Focused

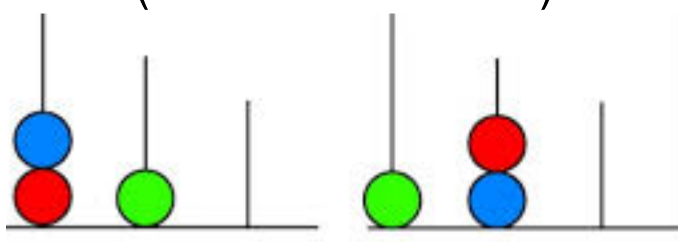


Look at animal face center

EMHMM co-clustering: cognitive ability and eye movement measures

Cognitive ability tests:

(1) Tower of London (ToL) (Executive function)



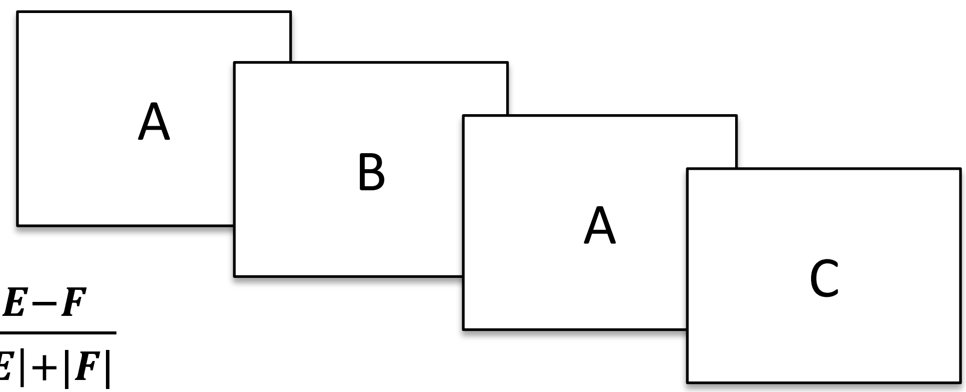
Starting position Goal position

(2) Flanker Task (Visual attention)

Congruent ←←←←←

Incongruent →→←→→

(3) Verbal & Visuospatial Two-Back Task (Working memory)



Similarity to Explorative pattern:

Explorative-Focused (E-F) scale = $\frac{E-F}{|E|+|F|}$

where

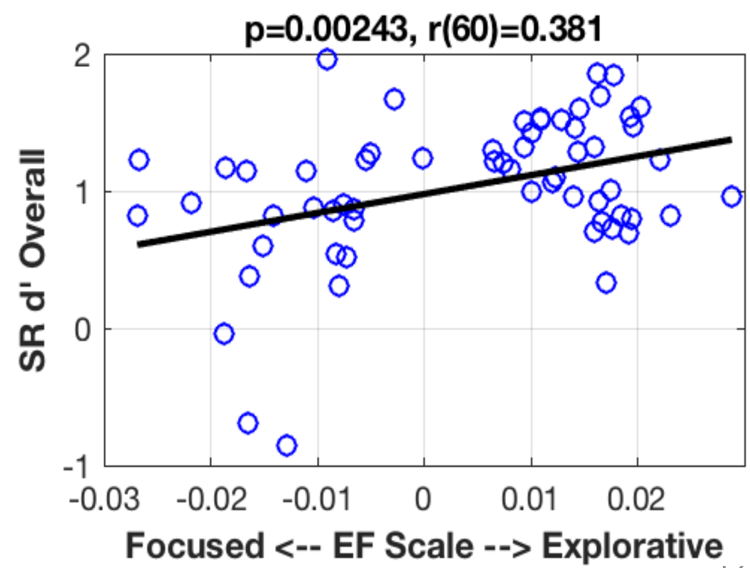
E = Data log-likelihood of Explorative pattern

F = Data log-likelihood of Focused pattern

EMHMM co-clustering: Foreground object recognition performance

- Stepwise multiple regression predicting recognition performance with all cognitive ability measures and E-F scale showed that only E-F scale (β = .364, p = .003) and visuospatial two-back task RT (β = .364, p = .003) were significant predictors. The overall model fit R^2 = .223.

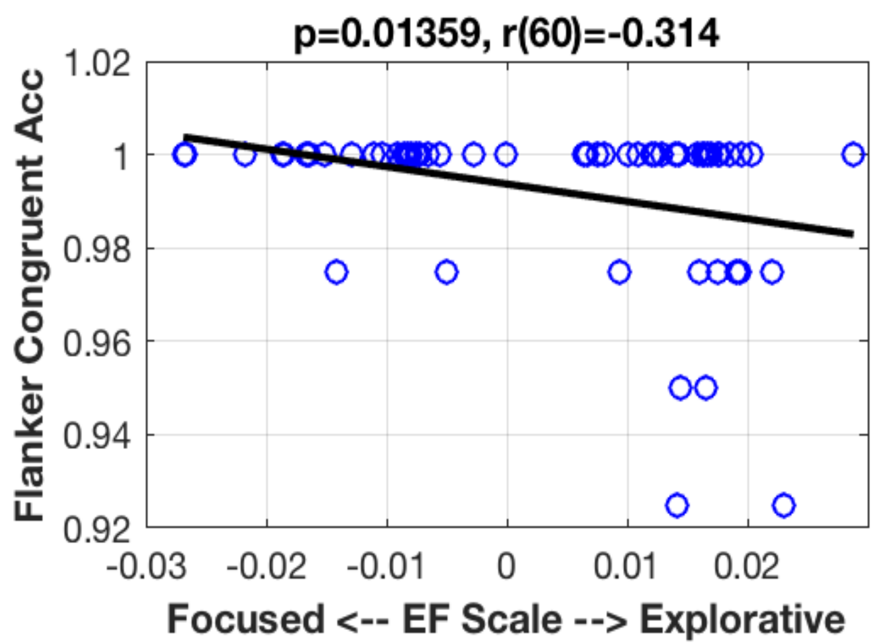
Higher similarity to Explorative pattern and **higher visuospatial WM capacity** predicted better foreground object recognition performance.



EMHMM co-clustering: Factors predicting eye movement pattern

- Stepwise multiple regression predicting E-F scale with all cognitive ability measures showed that <u>flanker task accuracy in congruent trials</u> (β = -.341, p = .007) and <u>ToL preplanning time</u> (β = .257, p = .039) were significant predictors. The overall model fit R^2 = .164.

Eye movement pattern in scene perception is particularly related to **visual attention** and **executive function.**



Conclusion & Discussion

- EMHMM revealed Explorative and Focused eye movement patterns among Asian participants.
- Explorative pattern was associated with better foreground object recognition performance regardless of whether the object appeared in an old or new background. It may be related to the availability of retrieval cues.
- Focused pattern was associated with better feature integration in the flanker task (visual attention) and more efficient planning in the ToL task (executive function).
- Images with a salient foreground object relative to the background induced larger individual differences in eye movements.
- Eye movements in scene perception contribute to object recognition performance and reflect individual differences in cognitive ability and scene preference.

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