Supplemental material: Nonlinear relationships between eye gaze and recognition accuracy for ethnic ingroup and outgroup faces

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A selective review of papers testing visual processing and recognition

Goldinger, He, and Papesh (2009)

- Methods
  - Asian and White participants
  - Asian and White faces
  - Encode-recognition task
- Results
  - Participants fixated more frequently on the eyes of ingroup than outgroup faces
  - Participants fixated less frequently on the nose and mouth of ingroup faces than outgroup faces
  - Participants performed more fixations and moved eyes further for ingroup faces than outgroup faces
  - Researchers subdivided their participants based on performance; those who more effectively remembered outgroup faces scanned the faces more extensively
- Conclusions
  - Evidence of differential encoding strategies and indirect evidence of effective behavior (with CR faces)
  - Note: This study did not formally test the relationship between gaze and recognition

Wu, Laeng, and Magnussen (2012)

- Methods

  - White participants
  - Asian and White faces
  - Encode-recognition task

- Results
  - Participants performed more and shorter fixations for ingroup faces
  - Participants performed more saccades for ingroup faces
  - Participants dwelled for a longer time on the eyes of ingroup faces
  - Participants dwelled for a shorter time on the nose of ingroup faces
  - The number of total fixations was greater on hit trials than on miss trials

- Conclusions
  - Evidence of differential encoding strategies and effective behavior.

Kawakami et al. (2014), Study 1

- Methods
  - White participants
  - Black and White faces
  - Encode-recognition task, with 2 faces presented at a time during encoding

- Results
  - Participants dwelled for a longer time on the eyes of ingroup faces

- Conclusions
  - Because of a related error in the analysis (see Correll & Hudson, 2020), we do not believe this work provides evidence of which behaviors promote recognition, but it does show evidence of differential encoding strategies

McDonnell, Bornstein, Laub, Mills, and Dodd (2014)

- Methods
  - White participants
  - Black and White faces
  - Encode-recognition task, with 2 faces presented at a time during encoding
  - Study 2 only: manipulation instructing some participants to attend to mouth of Black faces
- Results
  - Study 1: dwell time to mouth marginally predicted reduced recognition accuracy
  - Study 2: dwell time to mouth predicted greater recognition for White faces (in one condition only)
  - Study 2: dwell time to nose predicted greater recognition for Black faces (in both conditions)
  - Study 2: dwell time to eyes predicted reduced recognition for White faces (in one condition)
  - Note: one of few studies to use linear mixed models
- Conclusions
  - Little consistent evidence of effective behavior or differentially effective behavior

Stelter, Rommel, and Degner (2021)

- Methods
  - White participants
  - Asian, Black, Middle Eastern, and White faces
  - Encode-recognition task, with 2 faces presented at a time during encoding

- Results
  - Participants dwelled for a longer time on the eyes of ingroup faces
  - Participants fixated more frequently on the eyes of ingroup faces
  - More and shorter fixations predicted greater recognition
- Conclusions
  - evidence of differential encoding and effective behavior

Burgund (2021)

- Methods
  - Asian and White participants
  - Asian, Black, and White faces
  - Encode-recognition task, with 2 faces presented at a time during encoding
- Results
  - Participants dwelled for a longer time on eyes of Asian and White (compared to Black)
  - Participants dwelled for a longer time on the nose and mouth of Black (compared to Asian and White)
  - Dwelling longer on eyes predicted greater recognition in general
  - Dwelling longer on nose and mouth predicted greater recognition for Black faces
- Conclusions
  - Evidence of differential encoding and differentially effective behavior

conducted a study in which Asian and White participants viewed Asian, Black, and White faces. Results suggest that perceivers of both groups

As a set: Blais and colleagues (2008); Caldara and colleagues (2010), Kelly and colleagues (2011), and Hills and Pake (2013, Study 1).

- Methods vary
- Results
  - No evidence that processing depends on the *ethnicity* of the face.
  - Perceivers belonging different ethnic groups encode faces differently: White participants attend more to eyes of faces; Black and Asian participants attend more to mouth/nose of faces
- Conclusions
  - No evidence of differential encoding
  - Note: the research does not test effective behavior

Analytical model

The variance of each eye gaze predictor – each behavioral measure – was captured by the two indices described above: P.Mean and Extra.Attn. The formula for the model is presented below. The βs represent the intercept, the fixed linear effects of ethnicity and the two indices, the quadratic effect of Extra.Attn, and the interaction of ethnicity with the linear and quadratics effect of Extra.Attn. The α's represent random effects. For example, α_i^P represents participant-to-participant variation in participant mean recognition ratings, and α_i^{PxFR} represents participant-to-participant variation in the effect of ethnicity on recognition ratings. Critically, the quadratic effect of the extra attention index statistically tests for nonlinear effects. The coefficient for the quadratic term captures the curvature of the attention-recognition prediction line.

$$rating_{i,j} =$$
$$\beta_0 + \alpha_i^P + \alpha_j^F + (\beta_1 + \alpha_i^{PxFR}) * FaceEthnicity_j + \beta_2 * P.Mean_i + \beta_3 * Extra.Attn_{i,j} + \beta_4 * Extra.Attn_{i,j}^2 + \beta_5 * FaceEthnicity_j * Extra.Attn_{i,j} + \beta_6 * FaceEthnicity_j * Extra.Attn_{i,j}^2 + \epsilon_{i,j}$$

To help interpret the terms in this model, below, we provide definitions and an explanation of the question tested by each fixed effect. For the purposes of illustration, we are assuming that the model has been used to test the relationship between total fixations and recognition.

$rating_{i,j}$: Degree to which current face is rated higher on recognition scale than never-before-seen faces of the same ethnicity.

$\beta_0 + \alpha_i^P + \alpha_j^F$: Fixed Intercept + random intercepts for participant & face. What is the average recognition rating?

$(\beta_1 + \alpha_i^{PxFR}) * FaceEthnicity_j$: Simple effect of face ethnicity + random effects for participant. Do participants recognize White faces more accurately than Black faces? This is the test of the CRD.

$\beta_2 * P.Mean_i$: Simple effect of variation in mean level of attention. Do participants who perform more fixations to faces, on average, recognize faces more accurately?

$\beta_3 * Extra.Attn_{i,j}$: Simple linear effect of extra attention to current face. If a participant performs more fixations to the current face than what is typical for faces of the same ethnicity, does recognition improve?

$\beta_4 * Extra.Attn^2_{i,j}$: Simple quadratic effect of extra attention to current face. Does the benefit of an extra fixation change as the number of extra fixations increases? This tests nonlinearity.

$\beta_5 * FaceEthnicity_j * Extra.Attn_{i,j}$: Interaction of face ethnicity & linear effect of extra attention. Does the benefit of an extra fixation depend on the ethnicity of the face?

$\beta_6 * FaceEthnicity_j * Extra.Attn^2_{i,j}$: Interaction of face ethnicity & quadratic effect of extra attention. Does the curvilinear effect of extra fixations depend on the ethnicity of the face?

Reporting standards for eye tracking research

To improve transparency, we report the design and analysis decisions following recently suggested guidelines for eye-tracking research (Fiedler, Schulte-Mecklenbeck, Renkewitz, & Orquin, 2020).

- Introduction
  - State auxiliary assumptions about the underlying processes of dependent variables: We do not assume that eye gaze necessarily corresponds to cognitive processing, rather we estimate the extent to which eye gaze (as a measure of overt attention) is related to memory.
- Methods
  - Eye-tracker Model: EyeLink1000
  - Eye-tracker Producer: SR Research Ltd., Ontario, Canada
  - Eye-tracker Type: Desk-mounted
  - Monitor Resolution: 1280x1024
  - Monitor Size: 17”
  - Software used to pre-process the eye-tracking data: SR Research EyeLink Data Viewer
  - Stimulus presentation software: SR Research Experiment Builder
  - Absolute size of the AOIs: left eye: 155x150, right eye: 155x150, upper nose: 65x150, lower nose: 180x130, mouth 240x140
  - Relative size of AOIs and content within the AOIs: the eye AOIs (left and right, combined) account for 46500 pixels; the nose AOIs (upper and lower combined) account for 71% of that area; the mouth AOI accounts for 72% of that area.
  - Minimal distance between AOIs: 0 pixels
  - Overlap between the AOIs: AOIs did not overlap

  - Method for stimulus preparation: grayscaled in Photoshop
  - Luminescence matched: no (and we did not examine pupil size)
  - Inter stimulus interval: 1000ms
  - Length of fixation presentation: variable; participants were required to fixate on the dot before pressing the space bar to initiate the encoding trial.
  - Position of the fixation cross: center of the screen
  - Length of stimulus presentation: 7s
  - Counter balancing of the position: NA
  - Order of stimulus presentation: random per participant
  - Number of trials: 32
  - Settings and locations where data was collected: controlled laboratory environment

- Results
  - Monitoring of data quality during experiment: drift check during fixation at the start of each trial
  - Proportion of trials excluded for the analysis: 0 (though we did exclude the first fixation on each trial because the fixation dot initially constrained the location of the gaze)
  - Reasons for exclusion: NA
  - Number of participants excluded from the analysis: Study 1: 12; Study 2: 14
  - Quality threshold for data exclusion: NA
  - Percentage of lost data: roughly 5%
  - Aggregation method for fixations: We used the default settings in SR Research Eyelink Data Viewer, which defines fixations as non-saccades and non-blinks. Saccades in turn are determined by the saccade velocity threshold, which is 30 degrees per second, and the saccade acceleration threshold, which is 8000 degrees per second per second.

  - Additional transformation of the data: we computed the number of fixations per AOI per trial per participant, and the sum of dwell time per AOI per trial per participant.

- Discussion

  - Limitations due to the use of eye-tracking methodology: eye tracking measures overt attention, which may or may not correspond to the visual information that the participant is cognitively processing.

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