Advanced experimental methods for cognitive science: Eye-tracking and statistical techniques

Day 5:
Data analysis, visualisation and reporting

Fabio Trecca
Riccardo Fusaroli
School of Communication and Culture
Aarhus University

F19: Computational modeling for cognitive science

12/02/2019

Visual Search

- Some measures of eye movements during visual search are heavy tailed
- Is this related to intrinsic and extrinsic factors?
- 2 tasks:
    - 1) Find target in cluttered image
    - 2) Count N targets in cluttered image

Visual Cognition, 2014
Vol. 22, No. 6, 809–842, http://dx.doi.org/10.1080/13506285.2014.918070

Routledge
Taylor & Francis Group

Intrinsic and extrinsic contributions to heavy tails in visual foraging

Theo Rhodes, Christopher T. Kello, and Bryan Kerster

University of California, Merced, CA, USA

Eyes move over visual scenes to gather visual information. Studies have found heavy-tailed distributions in measures of eye movements during visual search, which raises questions about whether these distributions are pervasive to eye movements, and whether they arise from intrinsic or extrinsic factors. Three different measures of eye movement trajectories were examined during visual foraging of complex images, and all three were found to exhibit heavy tails: Spatial clustering of eye movements followed a power law distribution, saccade length distributions were lognormally distributed, and the speeds of slow, small amplitude movements occurring during fixations followed a 1/f spectral power law relation. Images were varied to test whether the spatial clustering of visual scene information is responsible for heavy tails in eye movements. Spatial clustering of eye movements and saccade length distributions were found to vary with image type and task demands, but no such effects were found for eye movement speeds during fixations. Results showed that heavy-tailed distributions are general and intrinsic to visual foraging, but some of them become aligned with visual stimuli when required by task demands. The potentially adaptive value of heavy-tailed distributions in visual foraging is discussed.

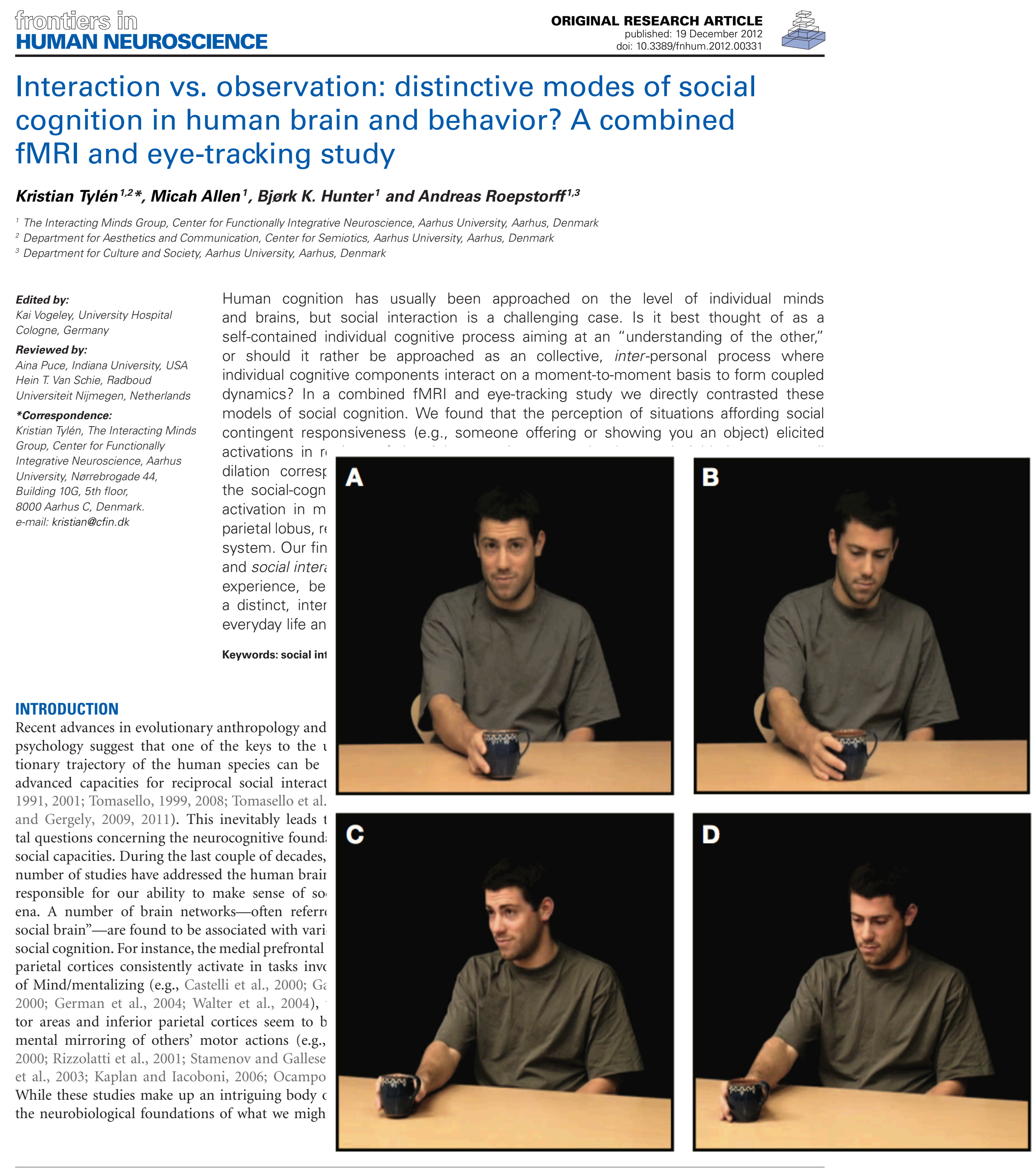
Keywords: Visual search; Foraging; Scene perception; Power laws; Lévy walks.

Eyes move to gather information about the visually accessible world in the service of behaviour. In scene perception, for example, visual features and objects are identified for guiding behaviour on immediate timescales of perception-action loops (e.g., Hayhoe, Shrivastava, Mruczek, & Pelz, 2003), and on longer range timescales mediated by processes of memory, planning, and communication

Please address all correspondence to Theo Rhodes, Department of Psychology, SUNY Oswego, 402 Mahar Hall, Oswego, NY 13126, USA. E-mail: theo.rhodes@oswego.edu
This research was supported by an award from the National Science Foundation [grant number BCS 1031903]. We would like to thank Krishna Vadrevu for his assistance in data collection and analysis.
Theo Rhodes' permanent address is at the State University of New York at Oswego.

Social Engagement

- Does situations affording social contingent responsiveness (vs. social observation) elicit greater responses associated with joint action?
- E.g., larger pupil size
- Different video-stimuli:
    - A: +ostensive +direct
    - B: -ostensive +direct
    - C: +ostensive -direct
    - D: - ostensive -direct



frontiers in HUMAN NEUROSCIENCE

ORIGINAL RESEARCH ARTICLE
published: 19 December 2012
doi: 10.3389/fnhum.2012.00331

Interaction vs. observation: distinctive modes of social cognition in human brain and behavior? A combined fMRI and eye-tracking study

Kristian Tylén[1,2]*, Micah Allen[1], Bjørk K. Hunter[1] and Andreas Roepstorff[1,3]

[1] The Interacting Minds Group, Center for Functionally Integrative Neuroscience, Aarhus University, Aarhus, Denmark
[2] Department for Aesthetics and Communication, Center for Semiotics, Aarhus University, Aarhus, Denmark
[3] Department for Culture and Society, Aarhus University, Aarhus, Denmark

Edited by:
Kai Vogeley, University Hospital Cologne, Germany

Reviewed by:
Aina Puce, Indiana University, USA
Hein T. Van Schie, Radboud Universiteit Nijmegen, Netherlands

***Correspondence:**
Kristian Tylén, The Interacting Minds Group, Center for Functionally Integrative Neuroscience, Aarhus University, Nørrebrogade 44, Building 10G, 5th floor, 8000 Aarhus C, Denmark.
e-mail: kristian@cfin.dk

Human cognition has usually been approached on the level of individual minds and brains, but social interaction is a challenging case. Is it best thought of as a self-contained individual cognitive process aiming at an "understanding of the other," or should it rather be approached as an collective, *inter*-personal process where individual cognitive components interact on a moment-to-moment basis to form coupled dynamics? In a combined fMRI and eye-tracking study we directly contrasted these models of social cognition. We found that the perception of situations affording social contingent responsiveness (e.g., someone offering or showing you an object) elicited activations in r dilation corresp the social-cogn activation in m parietal lobus, r system. Our fin and *social intera* experience, be a distinct, inter everyday life an

Keywords: social int

INTRODUCTION

Recent advances in evolutionary anthropology and psychology suggest that one of the keys to the u tionary trajectory of the human species can be advanced capacities for reciprocal social interact 1991, 2001; Tomasello, 1999, 2008; Tomasello et al. and Gergely, 2009, 2011). This inevitably leads t tal questions concerning the neurocognitive found social capacities. During the last couple of decades, number of studies have addressed the human brain responsible for our ability to make sense of so ena. A number of brain networks—often referr social brain"—are found to be associated with vari social cognition. For instance, the medial prefrontal parietal cortices consistently activate in tasks inv of Mind/mentalizing (e.g., Castelli et al., 2000; Ga 2000; German et al., 2004; Walter et al., 2004), tor areas and inferior parietal cortices seem to b mental mirroring of others' motor actions (e.g., 2000; Rizzolatti et al., 2001; Stamenov and Gallese et al., 2003; Kaplan and Iacoboni, 2006; Ocampo While these studies make up an intriguing body o the neurobiological foundations of what we migh

Frontiers in Human Neuroscience www.frontiersin.org December 2012 | Volume 6 | Article 331 | 1

AARHUS UNIVERSITET

Discussion of our hypotheses

- Our hypotheses exist on two different planes:
  - Conceptual
  - Operational

Hypotheses: Conceptual plane

- **Visual Search**:
  - VS patterns are affected by task structure and goals (top-down)
  - VS patterns are affected by stimulus structure (bottom-up)
  - Search direction is affected by cultural constraints (e.g., reading direction)

- **Social Engagement**:
  - More emotionally engaged when involved in interaction (~direction & ostensiveness)
  - Direction affects participant attention
  - More focus on person vs. cup when interaction is lead by eye contact
  - Sexual preferences
  - Familiarity effect

Hypotheses: Operational plane

- **Visual search:**
  Search patterns are affected by task structure and goals (top-down)
  - Fixations: duration
  - Saccades: N, amplitude
  - Bonus:
    - Searching directions: In Count task, early fixations haveMeanPosition < median(Position)
    - P(next jump == long jump)

Hypotheses: Operational plane

- **Social Engagement:**
  More emotionally engaged when involved in interaction (~direction & ostensiveness)

  - Pupil Size

  - Fixation duration

Portfolio – part 1

- The first assignment consists on the reports for the two eye-tracking experiments you conducted in the first two weeks of the course

- It allows you to consolidate (aka what the heck did I do last semester?) your Methods 3 statistical modelling and to have a template for reporting eye-tracking experiments in the future should you ever need to do so

Portfolio – part 1 (2)

- Github repositories with your analysis script
- 2 documents to submit
  - Visual Search Experiment
  - Social Engagement Experiment
- Methods / Results / Plots of each experiment

Portfolio – part 1 (3)

- **A short report should involve**:
  - a description of the hypotheses, with ideally (optional) a reference to cognitive science literature
  - a description of the experiment: participants, conditions, stimuli, etc. Make sure to connect hypothesis to design
  - a description of the preprocessing of the data (focused only on the variables you will use in the analyses), including a visualisation to illustrate how the data looks like
  - a description of the statistical models (with an explicit link to the hypotheses)
  - a description of the results, including visualizations
  - a brief discussion as to how the results impinge on the hypotheses: do they support it or not?

The methods – Data Collection

What's important?

• Eye-tracking specific exclusion criteria	• Participants were screened for potential issues that might affect sampling rate, such as glasses or makeup.
• System used and measures	• Monocular eye positions and pupil size were recorded at 1000 Hz using an Eye Link 1000 eye-tracker with head mount.
• Participant position	• Each participant was seated approximately 60 cm. in front of a 30-inch flat panel LCD monitor.
• Calibration and data quality	• Prior to data collection, the eye-tracker was calibrated using the in-built 9-point automated calibration procedure, which was repeated until the validation procedure reported average errors below 0.5.
• Integration with stimulus presentation	• The eye-tracker was linked and synchronized with a second computer running a PsychoPy implementation of the paradigm and continuously recorded time stamps for the initiation of stimulus exposure.

The methods – Data pre-processing

What’s important?

- Artefacts and event detection
- If present quality check
- If long experiment: drift check / drift correction

- The eye- tracking data (x/y coordinates, velocities and pupil size) were automatically pre-processed using the in-built DataViewer software. Artefacts were removed. Eye-blinks, saccades and fixations were identified.
- Validation error was used to exclude participants / model measurement error.
- Qualitative quality check was performed mapping eye-movements / fixations / scan-paths onto a random selection of N pictures
- Examples
  - The data were high-pass filtered at a 100 s cut off to counter calibration drift.
  - Systematic bias in fixation estimates on fixation crosses was estimated and positions were accordingly adjusted at every trial

The methods – Data analysis

What's important?

- Measures used
  - We used pupil size at the sample level as dependent variable / outcome; direction and ostension as predictors, while controlling for trial number and time from start of trial
- Models used
  - We employed a mixed effects / multilevel linear regression model.
  - Since pupil size distributions have been shown to follow an exponential distribution (REF, if any) and indeed presented a long tail, we included a log link to the model specification (de facto corresponding to a log-transform of the model.
  - Model equation
  - Time from start of trial was modeled as a third-degree polynomial to account for potential non-linear changes in pupil size over time
- Model selection / validity check
  - We employed a 5-fold cross-validation model selection procedure to identify which parameters should be kept in the model. Cross-validation was stratified at the participant level and balanced across conditions. We used out-of-sample error, operationalized as root mean square error as selection criterion.
  - The selected model was then ran on the full dataset to optimize parameter estimation.
- Statistical software
  - The models were implement using lme4 version xxx, cvms version xxx, etc. on Rstudio v xxx, and R v xxx (REFS)

The results

What's important?

- Model selected
  - Error?
- Effect sizes
  - Random effects?
- Significance
- Plots
  - Of the results
  - Illustrative plots

- The 5-fold cross-validation selection process yielded the following results:
  - Table with models and rmse
- The selected model is reported in table xxx:
  - Table with predictors, beta, se, p-value
  - Table with random effects?
- Plots

Discussion

- Summarize the goal of the experiment
- Indicate whether the results disconfirm or support the hypotheses
- [Discuss the relevance of the results in contributing to our knowledge of the phenomena investigated, their limitations and potentialities for future studies and, if overhyping, applications]

Optional questions

- Ddid the mishap in calibration in 2019 affect the results? How would you test for that?
- Individual differences are very important: are all participants showing the same results? Do they vary a lot? Discuss how you would go visualizing and describing individual variability and what you could learn from that.
- Could you imagine setting up a system to automatically adjust the threshold for Fixations vs. Saccades for each participant? There is some research doing so using machine learning algorithms. Do a google scholar search to see what is being done and list the **good** references.