iMap 4: An Open Source Toolbox for the Statistical Fixation Mapping of Eye Movement data with Linear Mixed Modeling

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A major challenge in modern eye movement research is to statistically map *where* observers are looking at, as well as isolating statistical significant differences between groups and conditions. Compared to signals of contemporary neuroscience measures, such as M/EEG and fMRI, eye movement data are sparse with much larger variations across trials and participants. As a result, the implementation of a conventional Hierarchical Linear Model approach on two-dimensional fixation distributions often returns unstable estimations and underpowered results, leaving this statistical problem unresolved. Here, we tackled this issue by using the statistical framework implemented in diverse state-of-the-art neuroimaging data processing toolboxes: Statistical Parametric Mapping (SPM), Fieldtrip and LIMO EEG. We first estimated the mean individual fixation maps per condition by using trimmean to account for the sparseness and the high variations of fixation data. We then applied a univariate, pixel-wise linear mixed model

(LMM) on the smoothed fixation data with each subject as a random effect, which offers the flexibility to code for multiple between- and within- subject comparisons. After this step, our approach allows to perform all the possible linear contrasts for the fixed effects (main effects, interactions, etc.). Importantly, we also introduced a novel spatial cluster test based on bootstrapping to assess the statistical significance of the linear contrasts. Finally, we validated this approach by using both experimental and computer simulation data with a Monte Carlo approach. iMap 4 is a freely available MATLAB open source toolbox for the statistical fixation mapping of eye movement data, with a user-friendly interface providing straightforward, easy to interpret statistical graphical outputs and matching the standards in robust statistical neuroimaging methods. iMap 4 represents a major step in the processing of eye movement fixation data, paving the way to a routine use of robust data-driven analyses in this important field of vision sciences.