Decomposing LLAMA-B: A Multimodal EEG and Eye-Tracking Investigation of Rapid Picture-Name Learning

Alireza Rahmanian (alireza.rahmanian@boun.edu.tr)[1], Zehra Betül Tuna[2], Gülcan Erçetin[2]
[1]Department of Cognitive Science, Boğaziçi University, Istanbul, Türkiye
[2]Department of Foreign Language Education, Boğaziçi University, Istanbul, Türkiye

A central debate in language-aptitude research concerns whether rapid vocabulary learning reflects vocabulary-relevant mechanisms for establishing arbitrary form-meaning associations or broader capacities involving attention, working memory, processing speed, and cognitive control [1,2]. LLAMA-B assesses the ability to learn unfamiliar names for unfamiliar objects [3], but its final recognition score combines multiple processes, leaving the basis of individual differences unresolved [4-6]. This preregistered study therefore combines LLAMA-B with simultaneous EEG, eye tracking, and targeted domain-general cognitive measures to identify the processes contributing to rapid picture-name learning.The sample will comprise 40 Turkish-L1 university students at Boğaziçi University. Participants will complete an n-back task indexing working-memory updating, a Pattern Comparison task indexing processing speed, and a Flanker task indexing inhibitory control, followed by the original LLAMA-B task. During learning, participants will freely explore 24 unfamiliar objects and their unfamiliar written names for three minutes, followed by the original recognition test and scoring procedure. To obtain precise timing and event markers, the original web-based task has been reimplemented in PsychoPy while preserving its stimuli, item count, participant-controlled exploration, learning duration, recognition format, and scoring system. EEG will be recorded continuously with a BrainAmp system at 500 Hz, and binocular gaze with a Tobii Pro Fusion eye tracker at 250 Hz. Behavioral, EEG, eye-tracking, and marker streams will be synchronized through Lab Streaming Layer. Time-locked markers will identify object selection, picture-name presentation, revisits, test onset, and responses. After the original test, participants will complete an EEG-compatible congruency-judgment task contrasting studied picture-name mappings with incongruent recombinations. The primary neural measure will be the centro-parietal N400 congruency effect from 300 to 500 ms [7,8]. Incongruent recombinations are predicted to elicit greater negativity than studied mappings, and larger participant-level effects are expected to predict higher LLAMA-B scores after accounting for domain-general cognitive performance. This effect will operationalize vocabulary-relevant semantic integration during the retrieval of newly established form–meaning associations [4,7,8]. Eye-tracking analyses will test a subsequent-memory hypothesis during learning. Later-recognized mappings are predicted to show greater dwell time on the unfamiliar name and more reciprocal transitions between picture and name than later-missed mappings. Dwell time will index sustained attention to the novel word form, whereas reciprocal transitions will index integrative sampling of form and referent [9,10]. Fixation latency and revisits will be examined as secondary measures. Trial-level mixed-effects models will predict recognition accuracy from neural, gaze, and cognitive predictors [11]. Confirmatory analyses will focus on the N400 effect, unfamiliar-name dwell time, and reciprocal picture-name transitions. Midfrontal theta and deconvolution-based fixation-related potentials will be examined as secondary and exploratory measures [12]. The analysis plan will define preprocessing, data-quality, reliability, multiplicity, and power-analysis procedures. A unique N400 contribution would support an additional role for vocabulary-relevant semantic integration; stronger cognitive and gaze contributions with little added N400 value would support an attention and a domain general account; and independent contributions would support a multicomponent account of rapid vocabulary-learning aptitude.

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