Spatiotemporal Dissociations for Fulfilling and Violating Predictions at Multiple Levels of Representation: A Multimodal Approach

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INTRODUCTION: There is growing evidence that we use linguistic context to predict at multiple levels of representation. Using multimodal imaging (ERP, MEG, fMRI), we asked whether and when distinct neuroanatomical networks are engaged to inputs that fulfill or violate strong contextual predictions generated at the level of specific lexical items and/or semantic-thematic structure.

METHODS: 32 subjects participated in fMRI and ERP/MEG sessions. They read and judged the acceptability of three-sentence scenarios that varied in their contextual predictability (High Constraint HC, Low Constraint LC) and in whether critical nouns in the third sentence fulfilled or violated contextual predictions and/or the selection restrictions (SRs) of their preceding verbs (examples below). The first two sentences appeared in full; the third sentence appeared word-by-word. Stimuli were counterbalanced across conditions, within and across fMRI and EEG/MEG sessions.

RESULTS: (1) ERPs showed selectively reduced activity on the N400 (300-500ms) to predictable critical nouns (HC_pred), relative to all other conditions, reflecting semantic facilitation. In fMRI, all these contrasts revealed reduced activity throughout the left anterior temporal lobe (ATL) and within the left inferior frontal gyrus (IFG). MEG source localization showed that only the left ATL was modulated within the N400 time window. (2) Nouns that violated high constraint contexts (HC_lexviol) selectively evoked an anteriorly-distributed positivity ERP between 600-1000ms, relative to all other conditions. In fMRI, all these contrasts revealed activity not only within the left ATL and IFG, but also within the left-lateralized posterior superior/middle temporal gyrus (S/MTG), premotor cortex (PC) and inferior parietal lobule. MEG source localization within the later time window revealed enhanced activity within the left post-S/MTG and PC. (3) Words that violated the SRs of their preceding verbs (HC_SRviol) selectively evoked a larger posteriorly-distributed positivity/P600 ERP between 600-1000ms, relative to all other conditions. In fMRI, all these contrasts revealed modulation within the left ant-DLPFC and right motor cortex. MEG source localization within the later time window revealed modulation within the left ant-DLPFC.

DISCUSSION: These findings provide strong evidence that the brain engages partially distinct networks, distinguished both in their timing and neuroanatomical localization, in response to inputs that fulfill versus violate strong predictions. Incoming words that fulfill strong lexico-semantic predictions are associated with reduced activity within left ATL between 300-500ms. Inputs that violate strong lexical predictions lead to the additional engagement of left IFG and post-STG, perhaps reflecting prolonged attempts to retrieve unpredicted lexico-semantic items, and infer the event dictated by the bottom-up input. Inputs that violate semantic-thematic predictions, however, lead to the engagement of a distinct region – the ant-DLPFC, perhaps reflecting prolonged efforts to relate the properties of the verbs and arguments, thereby inferring novel event structures dictated by the bottom-up input.
EXAMPLE STIMULI
The lifeguards received a report of sharks near the beach. Their immediate concern was to prevent any incidents in the sea. Hence they cautioned the… swimmers (HC_pred); trainees (HC_lexviol); drawer (HC_SRviol)…
Eric and Grant received the news late in the day. They decided it was better to act sooner than later. Hence, they cautioned the… trainees (LC_unpred).