Accumulation of object evidence from multiple senses

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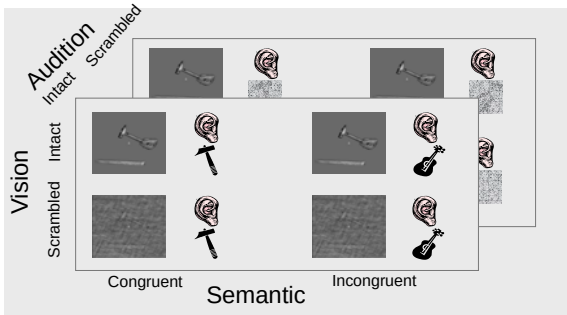
Introduction

To form categorical decisions about dynamic objects in our environment, the human brain accumulates noisy sensory information over time till a decisional threshold is reached. Temporal integration of visual evidence during object categorization and motion discrimination has been shown to rely on ramp-like neuronal activity in dorso-lateral prefrontal (DLPFC) and lateral intraparietal (LIP) cortices. However, in our natural environment, perceptual decisions are based on evidence from multiple senses. Here, we investigate the neural systems that accumulate multi-sensory evidence during categorization of dynamic audio-visual objects.

Experimental Design

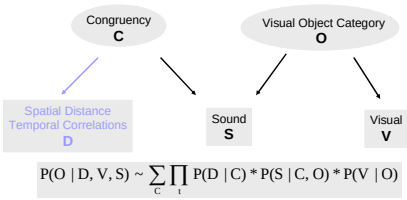
- 2 x 2 x 2 factorial design manipulating:
  - Visual informativeness (intact vs. degraded)
  - Auditory informativeness (intact vs. degraded)
  - Semantic incognruency (incongruent vs. congruent)

- Visual selective attention paradigm: Subjects performed speeded categorization of the visual movie, while ignoring soundtrack

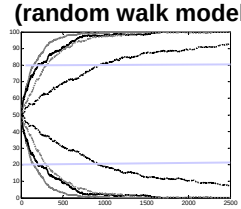


Scientific Questions & Predictions

Generative Model



Accumulation of evidence (random walk model)



- Reaction times as a marker for the time to decisional threshold :
  - Visually degraded > intact trials
  - Incongruent > congruent
  - Interaction between congruency and visual informativeness.

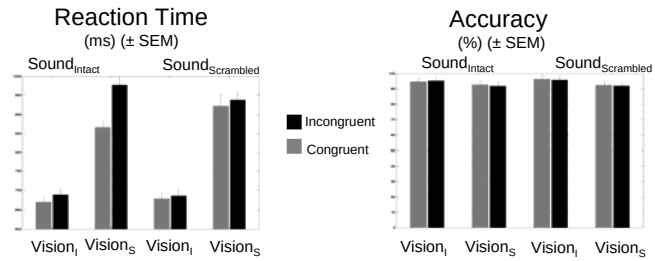
The incongruency effect should increase with the variance of the visual input that needs to be categorized and the reliability (=informativeness) of the irrelevant auditory input.

Using fMRI, we then tested for brain regions showing a qualitatively similar activation pattern. Candidate regions for accumulation of multi-sensory evidence were identified through conjunction of two orthogonal effects: (1) positive prediction by reaction times & (2) interaction between visual informativeness and semantic congruency.

Data Analysis

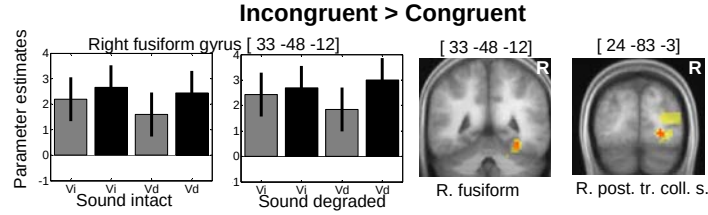
- Data acquisition:
  - SIEMENS 3T scanner, GE-EPI, TE=40ms, 38 axial slices, TR = 3.08s, voxel size 3x3x3 mm.
  - 2 sessions, 320 volumes each, 19 subjects.
- Data Analysis:
  - SPM2/5, Event-Related Analysis (HRF, temporal derivative).
  - Reaction times modelled as one single regressor
  - Random Effects Analysis, t-tests, $p < 0.05$ corr. for spat. extent.

Behavioral Results

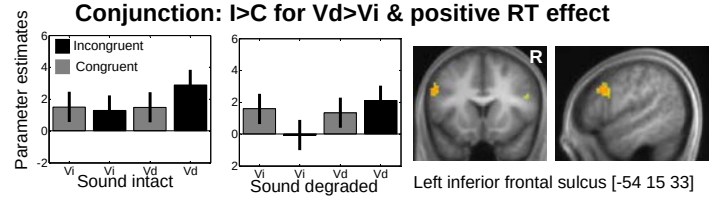


fMRI Results

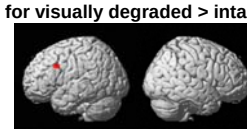
Incongruent > Congruent



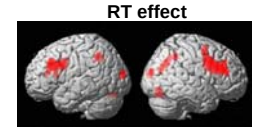
Conjunction: I>C for Vd>Vi & positive RT effect



Incongruency effects for visually degraded > intact



Positive RT effect



Summary & Conclusions

- RT accord with random walk models of perceptual decision making:
  - RT ↑↓ for visually degraded stimuli with intact incongruent sound
- Incongruent auditory movies induced amplification of the task-relevant visual information in right fusiform and posterior occipital gyrus.
- Activation in left IFS (1) predicted by RT and (2) showed incongruency effects that were increased for unreliable (=degraded) visual and interfering reliable (=intact) auditory information.

The IFS may be involved in accumulating multi-sensory evidence about object category over time to form interpretations and decisions that guide behavioural responses.