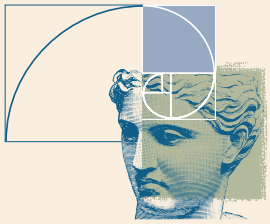
Cross-modal interactions of audio-visual information defined by space and time: A functional neuroimaging study



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Introduction

- The principles underlying cross-modal integration of auditory-visual information have been explored in several animal models using neurophysiological and behavioural approaches.
- However, cross-modal integration is poorly understood, particularly in the human nervous system.

Purpose

- To study the neural correlates of auditory and visual interactions defined by spatial and temporal factors.
- To examine if such neural correlates are found to form dissociable networks or largely form a unitary network within which spatiotemporal processing of auditory and visual information interact.

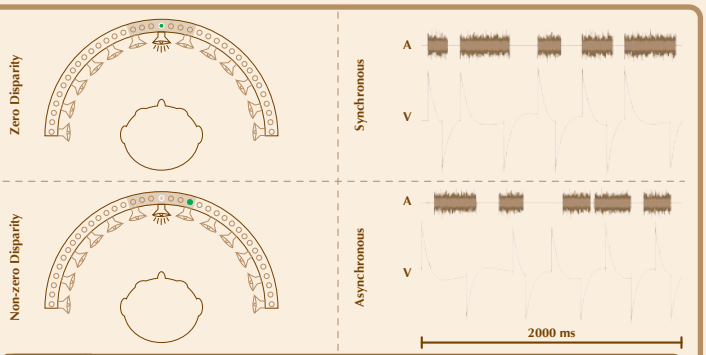
Methods

Participants and apparatus

- Thirteen young, healthy right-handed individuals were recruited.
- Stimuli were presented using a circular array (radius 24 cm) containing mini speakers and LEDs positioned 15˚ and 5˚ apart, respectively (see figure).
- Cerebral blood flow (CBF) was measured with a Siemens HR+ scanner and the H_2O^{15} bolus method.

Tasks

- Outside scanner: rating of whether audio and visual events form a unitary event or not.
- Inside scanner: fixation on the central LED of the array during scan sessions (otherwise, passive).

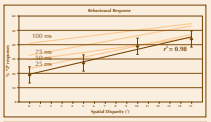


Condition	NS	AO	VO	AV1	AV2	AV3	AV4	AV5	AV6	AV7	AV8	AV9
Disparity	N/A	N/A	N/A	0˚	0˚	0˚	0˚	5˚	10˚	15˚	5˚	15˚
Asynchrony	N/A	N/A	N/A	0 ms	30 ms	60 ms	120 ms	0 ms	0 ms	0 ms	30 ms	120 ms

Spatial Disparity

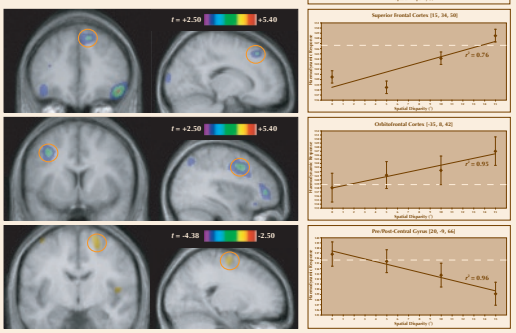
Psychophysics

Subjects' ratings of perceptual fusion of audio-visual stimuli are plotted as a function of increasing spatial disparity. Increasing spatial disparity leads to perceptual separation of audio and visual events.



Neuroimaging

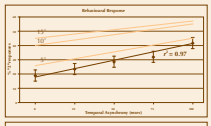
Representative areas of significant CBF change as a function of increasing spatial disparity are found in the middle panel. While some regions appear to reduce their response to synchronous stimuli with zero disparity, others increase their rCBF in response to increasing spatial disparity. In all cases, the dashed line shows the baseline rCBF.



Temporal Asynchrony

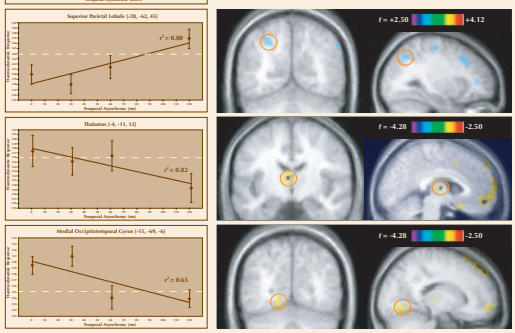
Psychophysics

Subjects' ratings of perceptual fusion of audio-visual stimuli are plotted as a function of increasing temporal asynchrony. Increasing temporal asynchrony leads to perceptual separation of audio and visual events.



Neuroimaging

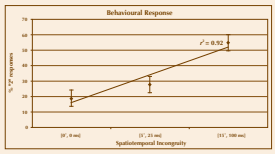
Representative areas of significant CBF change as a function of increasing temporal asynchrony are found in the middle panel. While some regions appear to reduce their response to synchronous stimuli with zero disparity, others display a direct relationship between rCBF change and increasing temporal asynchrony. In all cases, the dashed line shows the baseline rCBF.



Spatiotemporal Incongruity

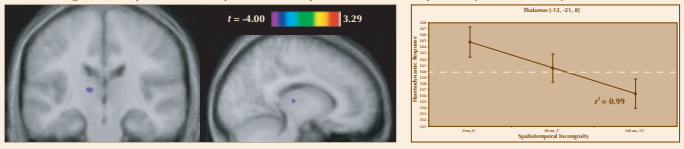
Psychophysics

Subjects' ratings of perceptual fusion are plotted as a function of increasing spatial disparity and temporal asynchrony. Simultaneous increases in spatial disparity and temporal asynchrony lead to percetual separation of audiovisual events more readily.

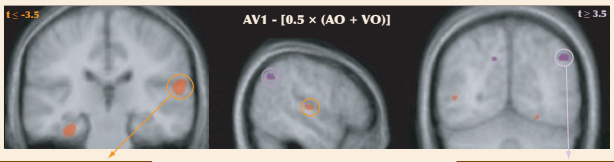


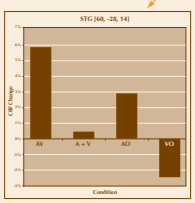
Neuroimaging

The thalamus was found to be amongst a handful of structures that show significant haemodynamic response to spatiotemporal incongruity. In addition, this is the only brain region that shows a significant rCBF change to independent manipulations of space and time (as per conjunction analyses).

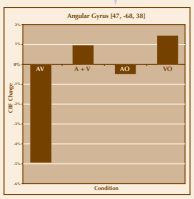


Superadditivity





Areas that showed significant haemodynamic response in the AV1 - [0.5 × (AO + VO)] contrast were further examined for the pattern of blood flow change during each experimental condition. While the STG shows positive superadditivity in response to AV stimuli [AV1 (0˚, 0 ms)], the angular gyrus exhibits a similar response pattern but in the opposite direction.



Summary/Conclusions

- Although the degree of perceptual separation of auditory and visual events increases as a function of increasing spatial disparity and temporal asynchrony, the two factors do not interact at the behavioural level.
- Brain regions repponsive to spatial and/or temporal manipulations of auditory and visual stimulations were not found in any known unimodal or multimodal regions. Rather our study has revealed a network of parieto-frontal cortical regions as well as a number of subcortical structures (e.g., thalamus) to be sensitive to such manipulations.
- Those brain regions were found to have categorically different response properties to saptiotemporal manipulations. Some regions appear to have a preference for congruity whereas some appear to detect incongruity.
- Given the overall lack of convergence of brain activity in response to independent spatial and temporal manipulations (except for the thalamus), it is conceivable that there are two independent networks for the processing of spatial and temporal factors that define the unity of audiovisual events.
- Applying the electrophysiological criteria to haemodynamic response data revealed instances of supperadditivity primarily in unimodal sensory cortical regions that appear to respond significantly more to synchronous audiovisual stimuli with zero disparity than to the sum of responses to unimodal stimuli.

Acknowledgements

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