Evidence for Sensitivity Adjustment in the Auditory Cortex during Audio-Visual cross-modal fMRI

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Purpose

Cross-model audiovisual paradigms allow to analyze the interplay between different activated brain areas as well as the processes involved in building a unified perception from separated sensory inputs such as in the ventriloquist effect [1]. It was shown that matching and mismatching acoustic and visual information would lead to different activation patterns in uni- and cross-modal cortical areas [2]. To gain inside into time-dependent processes not only the overall activation of the cortical areas [3] but also the time-course of the so-called hemodynamic response function (HRF) was monitored [4]. The aim was to unravel dynamic changes that relate to the association between visual and acoustic information of the same object and its consequences for the representation of this object if only part of this information is available.

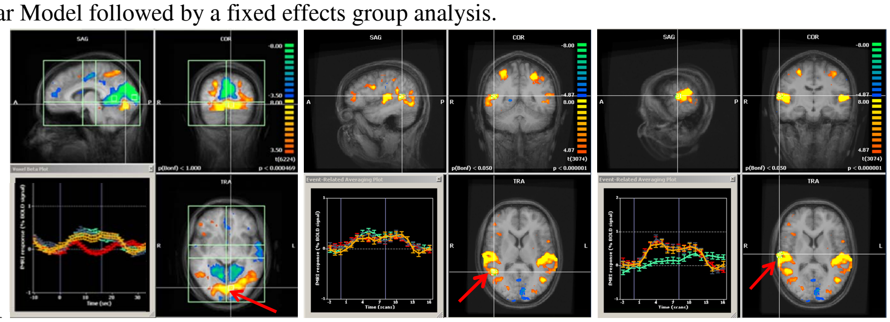
Methods

6 healthy volunteers were examined after giving written consent. The study was approved by the local ethics committee of the university clinic of the Otto-von-Guericke University Magdeburg according to the declaration of Helsinki. Measurements were performed on a 3 T whole body scanner (Trio, SIEMENS, Germany, Syngo VA25A; gradients 40mT/m, 8 element phased-array head coil, Siemens Medical). The protocol included an anatomical data set (MPRAGE, $1mm^3$ isotropic), and gradient-recalled EPI measurements for fMRI ($3.25x3.25x3\ mm^3$, slice gap 10%, TR = 2 s, 32 slices in axial-to-oblique positioning, parallel to the upper temporal gyrus, matrix size 64x64). The acoustic stimuli, generated using DirectX (Microsoft Company, Redmond, WA, USA), consisted of white noise (static or moving horizontally). Visual stimuli consisted of a red 3D ball moving horizontally. The study used a block-design with a pseudo-random distribution of four conditions: a) matching condition: noise and ball moving coherently; b) isolated visual condition: ball moving without noise; c) isolated acoustic condition: moving noise without visual stimulus; d) non-matching condition: noise moved from left to right while visual stimulus moved from right to left and vice versa. Three functional localizer were run prior to the main paradigm (8Hz flickering checkerboard to localize visual areas, a random dot pattern moving radially in and out to localize motion-sensitive area MT+/V5, and a block of static and moving white noise to identify auditory cortex areas responsive to noise). Data were analyzed with Brain Voyager (brainvoyager.com) using a General Linear Model followed by a fixed effects group analysis.

Results and Discussion

Fig. 1 shows activation and HRFs averaged over the events in representative cortical regions for the different conditions: matching visual and acoustic stimulus (dark blue curve), isolated acoustic stimulus (red), isolated visual stimulus (green), and non-matching visual/acoustic stimulus (yellow). No major differences in the activation were seen in the visual cortex (VC, Fig. 1a), auditory cortex (AC, Fig. 1c) and visual-acoustic cross-modal cortex (Fig. 1b) between matching and non-matching cross-modal conditions. The lingual gyrus as part of the VC (Fig. 1a) did also not show major differences between uni-modal visual and cross-modal audio-visual conditions while two short activation changes can be seen in the uni-modal acoustic condition. These may be interpreted as on-off-activation when a stimulus is presented after the resting condition. Most surprisingly a linear ramp-like increase of the HRF was seen in the AC during presentation of a visual stimulus without any white noise (green curve in Fig. 1c). As uni-and cross-modal stimuli were pseudo-randomly distributed it may be hypothesized that a prior association between the visual and acoustic information to the same objects was established and that the mere expectation of an acoustic signal triggers this activity while the VC is perceiving the corresponding visual information of the object. The lack of an acoustic signal may be interpreted by the brain as a stimulus below detection threshold. Therefore, adjusting the sensitivity in AC probably leads to a more sensitive detection of the ambient scanner noise that is due to the EPI sequences. Thus, an unconscious adaptation of the sensitivity of the AC as a result of an internal expectation may lead to the observed linear increase of the activation even if the external stimuli remain unchanged.

Fig. 1



a) Occ. lobe, lingual gyrus, BA18 b) middle temp. gyrus, BA21 c) sup. temp. gyrus, BA22

Conclusion

To the best of our knowledge this is the first time that a linear ramp-like increase of the HRF during a block-stimulation is detected although the external stimulus did not change. Thus, rather an internal adaption to an expected stimulus may be the underlying cause. However, a larger group must be examined and more cortical areas analyzed to confirm these results.

References

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