Multisensory Integration in Non-Human Primates and Human Beings

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Introduction

The nervous system of non-human primates and human beings has evolved to process information, first in separate sensory channels, and then integrate the sensory attributes from different sensory modalitities in order to extract, as efficiently as possible, cues from our complex and continuously changing environment. The coherent perception from different modalities, referred to as multisensory integration, takes place in associative cortical areas, but may also occur at early stages involving sub-cortical regions (e.g. thalamus). From a behavioural point of view, multisensory integration allows improvement of perceptive threshold (decrease of reaction times and/or less errors of detection).
Several studies and data (presented here) collected in our laboratory allowed to verify the behavioural correlates of the multisensory integration in non-human primates and human beings.
The aim of this study: To correlate neural activity to behavioural multisensory effects. To do this, neuronal recordings were derived from the auditory cortex and the premotor cortex in monkeys, as well as EEG recordings in human subjects.

Methods

Subjects: N=10 human subjects.
N= 2 non-human primates (*Macaca fascicularis*).

Stimuli:
Visual: Green light-emitting diode (LED) flash (1.9 mm circle) of 250 msec. inside a white target (2 cm) on black background.
Acoustic: Noise bursts of 250 msec.
Visuo-acoustic: Simultaneous presentation of the same visual and acoustic stimuli.

Intensity: **(for behavioural studies)**
Human: At 10, 20, and 30 dB above sensory thresholds.
Monkey: At 10 dB above sensory thresholds.

Thresholds: Obtained with an adaptive method (combination of the descending and ascending method). Obtained before multisensory session recordings.

Electrophysiological recordings:

Human: Performed with a **EEG** cap containing 65 active electrodes regularly distributed over the scalp (actiCAP, Brain product GmbH, Gilching, Germany) at 30 dB above sensory thresholds.
SEPs data were analysed with the Cartool software (http://sites.google.com/site/fbmlab/cartool) and computed against the average reference.

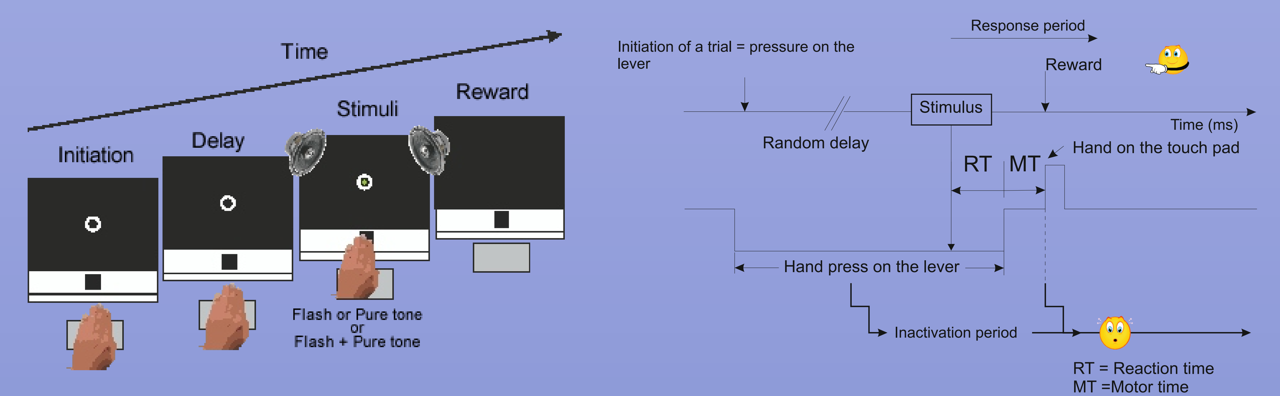
Monkey: Performed with single neuronal recordings in premotor and auditory cortex.
Data were analysed with MATLAB and Tucker Davis Technologies.

For each subject
The movements of subject's head were restricted by using a modified chin-rest. Furthermore the gaze was fixed and, in addition, the eye position was controlled using an ISCAN eye-tracking system.

Behavioural Task

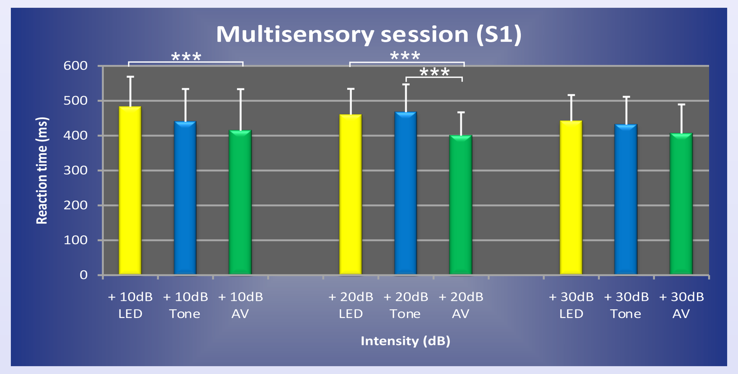
Psychophysical method based on automated behavioural procedure with positive reinforcement.

Controlling system designed with MATLAB, Labview and Tucker Davis Technologies.

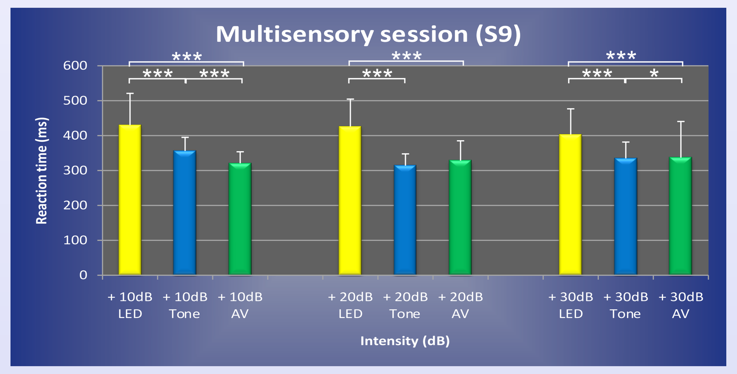


Behavioural Results

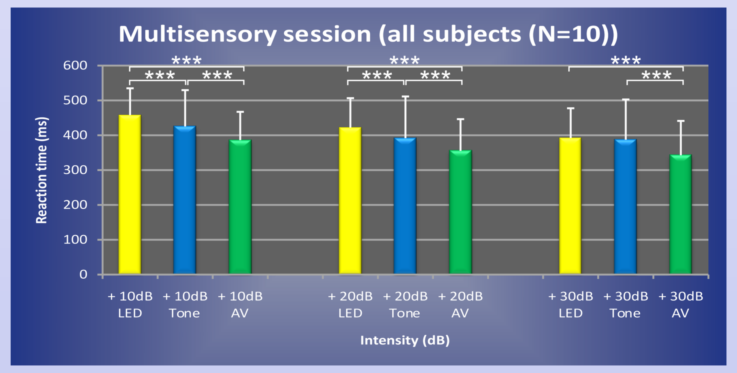
Human



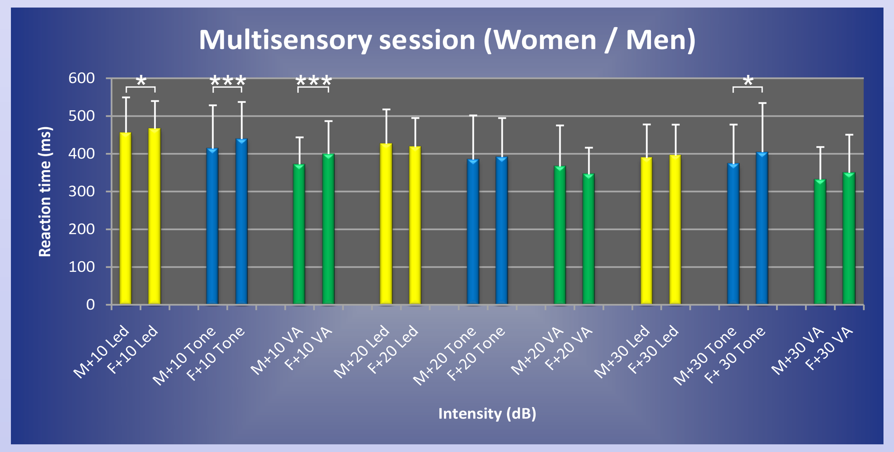
At +10 dB above threshold, a strong facilitatory multisensory effect was observed between V-AV.
At +20 dB we observed a significant effect between A-AV and V-VA.
At +30 dB no significant multisensory effect was observed.



At +10 dB above threshold, a strong facilitatory effect between V-AV and A-AV was observed.
Increasing intensities showed a decrease or an absence of significant multisensory effect between A-AV.

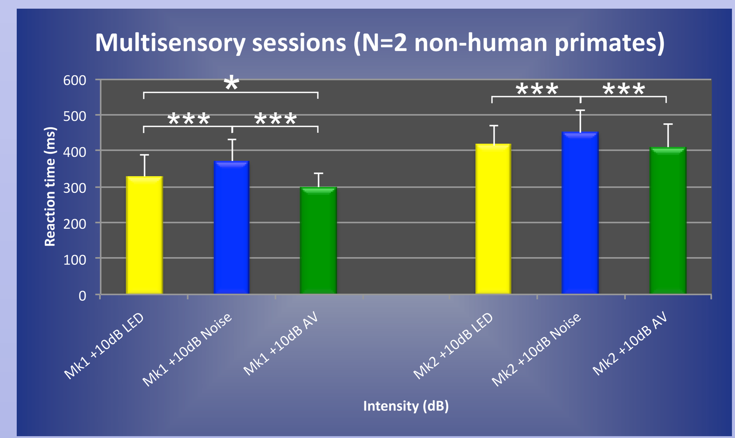


A facilitatory effect was observed between V-AV and A-AV at all three intensities above threshold.
At + 30 dB the facilitatory effect decreased but remained significant.
Reaction time for the auditory stimulus was shorter than for the visual stimulus at the three intensity conditions.



The comparison between genders shows that at **+10 dB** above threshold male (M) subjects are faster than female (F) subjects for every task. But at **+ 20** and **+ 30 dB**, there is no significant difference between women and men, except for the noise at **+ 30 dB**.

Non-Human Primates



At +10 dB above threshold, a strong facilitatory effect between A-AV was observed.
A facilitatory effect was observed between V-AV for Mk1.

Conclusions

Reaction time
For human subjects the reaction times in response to auditory stimuli were shorter than to visual stimuli. The comparison between all subjects showed that when the stimuli intensity increased, this difference of reaction time decreased.

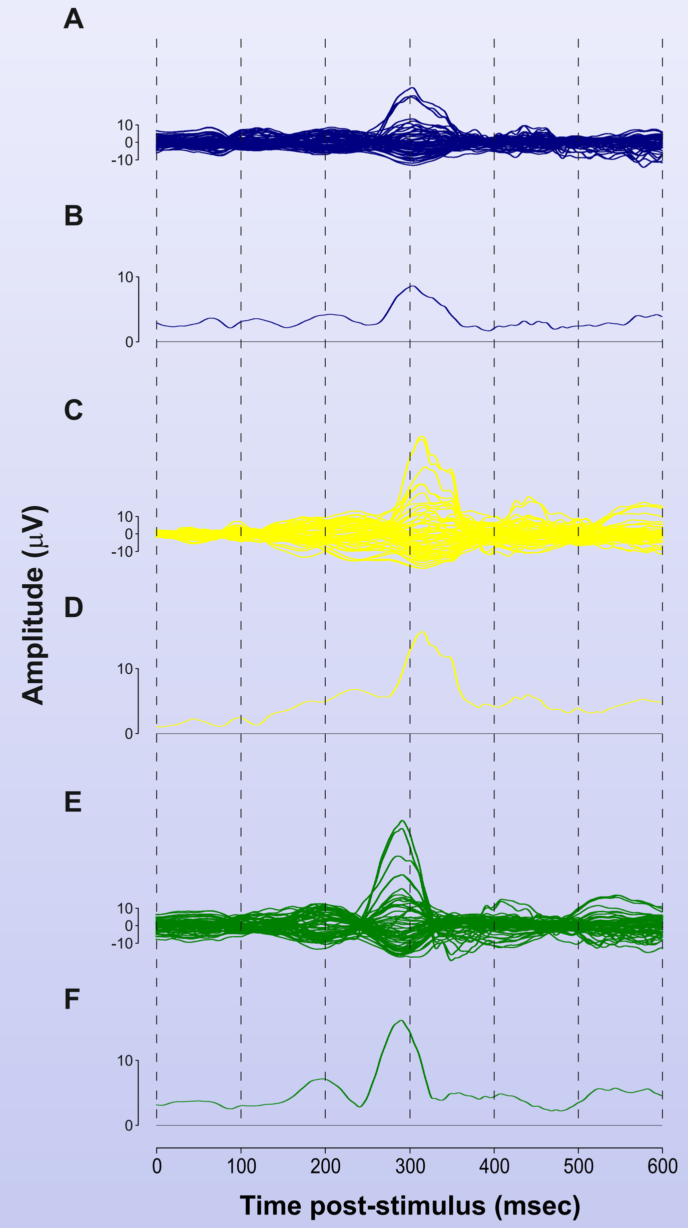
For non-human primates the reaction times in response to visual stimuli were shorter than to auditory stimuli. At higher intensity, reaction times to auditory stimuli were shorter than to visual stimuli (Cappe et al., 2010).

Facilitory
For human subjects the facilitatory multisensory effect decreased when the intensities of the stimuli increased. This inverse effectivness effect did not disappear for every subject at the same intensities. It disappeared at + 30 dB above threshold (for ex.: S1) but, in other subjects, there was still a significant facilitatory effect (S9).

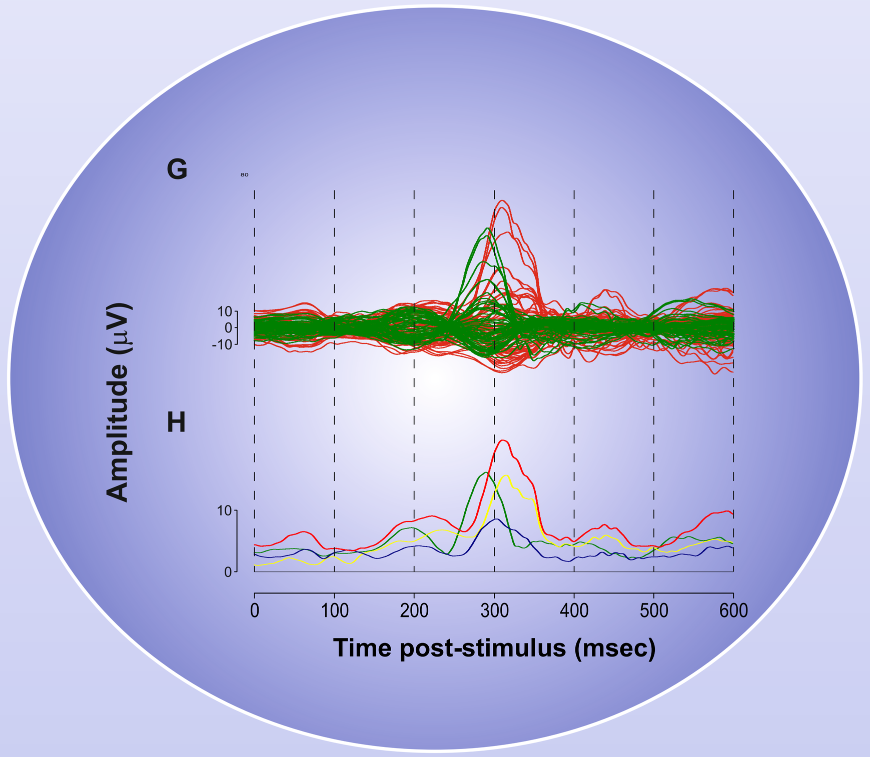
For non-human primates the data revealed a facilitatory multisensory effect at 10 dB above sensory thresholds. This effect was more significant for Mk1 than for Mk2.

Preliminary Electrophysiological Results

SEPs in Human

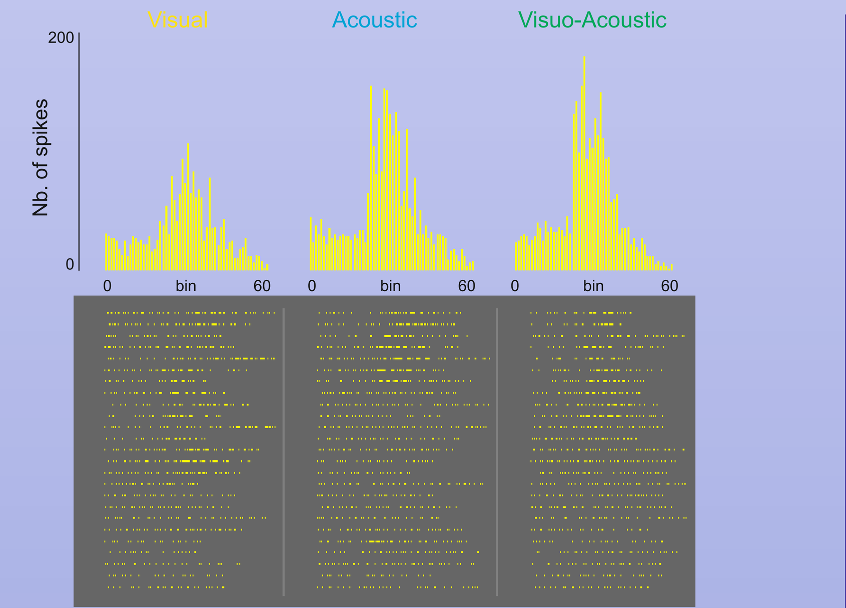


The Global Field Power (GFP) analysis showed a difference in the amplitude and the latency of the Sensory Evoked Potentials (SEPs), according to the type of stimulus (Graphs A-F). During the multisensory task, the latency was shorter than in response to unisensory stimuli. The amplitude of the evoked response was also larger.
In line with the behavioural data, the SEPs in response to unisensory stimuli showed that the latency was shorter for the auditory than for the visual stimulus (Graphs B and D).

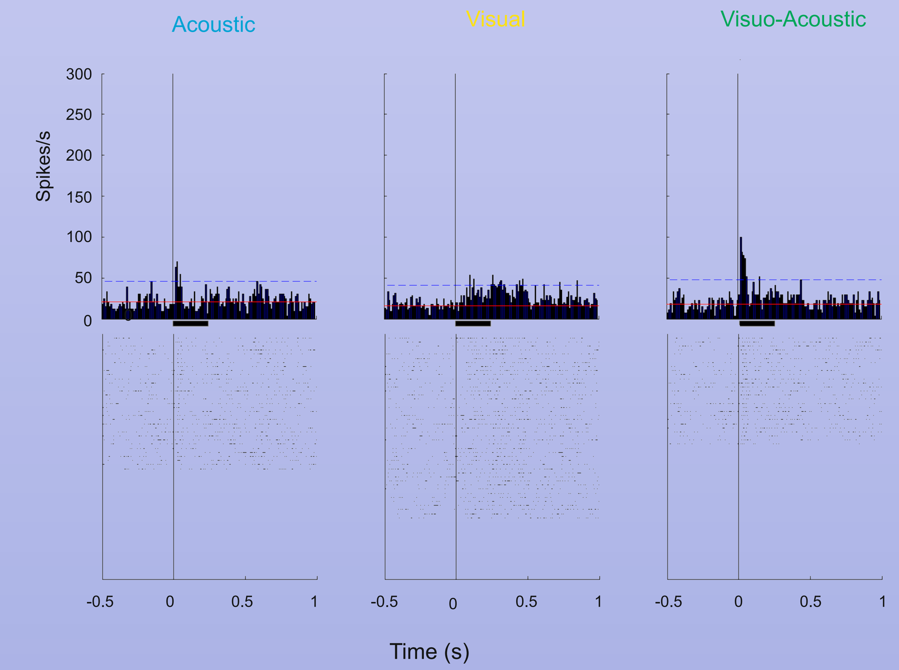


However, as a result of a comparison of the multisensory SEPs with the SEPs representing the summation of the visual and the auditory stimuli (Graphs G-H), we observed that the multisensory amplitude was lower than the summation, whereas the latency was shorter.

Neuronal activity in Non-Human Primates



PSTH (= peri-stimulus time histogram; top panel) and dot rasters (bottom panel) illustrate one example of neuronal activity recorded from a single neuron **in the premotor cortex**. Binwidth=150 msec. The activity is influenced by the type of sensory stimulus (to detect), although the motor response was identical in the 3 conditions.



PSTH and dot rasters illustrate one example of neuronal activity recorded from a single neuron **in the auditory cortex**. There is a facilitatory multisensory effect, as the response to the acoustic stimulus alone is enhanced when the visual stimulus was delivered simultaneously

Conclusions

For Human subjects, preliminary data show that the present multisensory paradigm is suitable for electrophysiological recordings (SEPs). However, the acquisition conducted so far at relatively high intensities (visual and auditory: around 40 dB above threshold) did not allow to demonstrate the facilitatory multisensory effect in term of SEPs amplitude, due most likely to the principle of inverse effectiveness. There was however an effect on the latency of the SEPs. For upcoming studies, the tests will be conducted closer to sensory thresholds as well.

For Non-Human Primates, in the premotor cortex, preliminary data show the presence of (motor-related) activity modulated by the type of sensory stimulus. In the auditory cortex, facilitatory multisensory effects were observed. Future investigations will be conducted in the thalamus (e.g. pulvinar nucleus) to search for evidence of early multisensory convergence.

Supported by Swiss National Science Foundation (grant 110005 to EMR) and NCCR Neuro