When neurons in auditory cortical areas respond to visual stimuli: electrophysiological data from monkeys performing an audio-visual detection task.

Cappe C.* (1,2), Loquet G. (1), Barone P. (2) and Rouiller E.M. (1)

* E-mail : Celine.Cappe@unifr.ch

(1) Unit of Physiology, Department of Medicine, University of Fribourg, Switzerland

(2) Centre de Recherche Cerveau et Cognition, CNRS/UPS UMR 5549, Faculty of Medicine Rangueil, Toulouse, France.

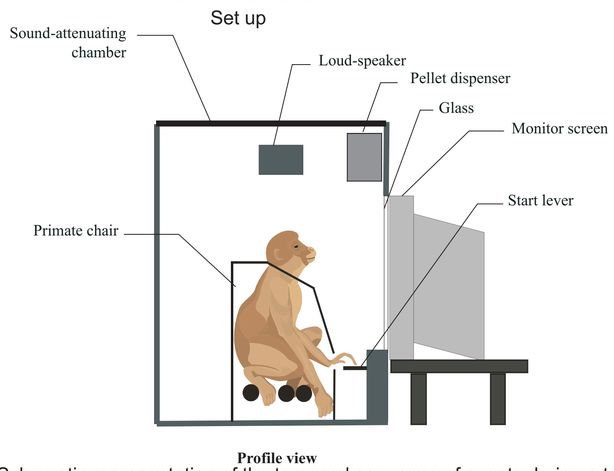
Introduction

On the psychophysical point of view, as compared to unimodal stimuli, multisensory integration allows improvement of perceptive threshold, as reflected by a decrease of reaction time and better performance in sensori-motor tasks. While such effects have been largely reported for human subjects in auditory-visual recognition tasks, only few data are available in behaving monkeys engaged in similar protocols. Multisensory integration is believed to take place mainly in higher order cortical areas. On a behavioral point of view, we have investigated the interaction between auditory and visual stimuli in monkeys. Moreover, the present study aimed at exploring the mechanisms underlying multisensory integration at the level of single neurons during a multisensory motor task in a cortical region considered as unimodal, a dimension that cannot be assessed in human subjects.

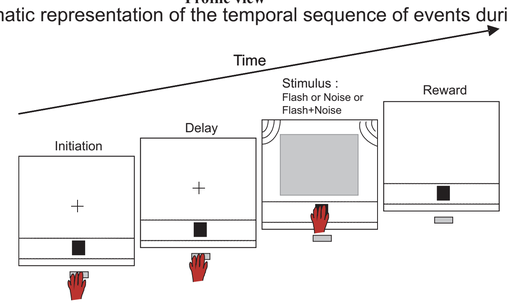
Stimuli for electrophysiological recordings

Visual stimuli : flash on the screen in front of the animal (9.2 Lux).
Auditory stimuli : noise burst from 2 loudspeakers on each side of the screen (40 or 60 dB SPL).
The duration of stimuli was 250 ms.

Methods

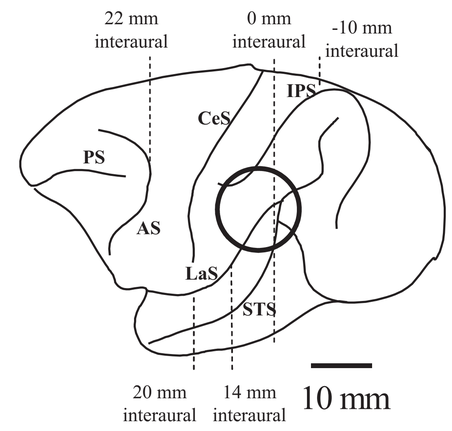


Schematic representation of the temporal sequence of events during a typical trial



Two adult Macaca fascicularis were trained to perform a visuo-acoustic detection task. To initiate a trial, the monkey has to place his left hand on a starting pad, the fixation point on the monitor facing the monkey is turned on and the monkey has to fixate during the entire trial. The initiation of the trial is followed by a random delay. Then, the sensory cue is presented, consisting of a unimodal visual (V) or auditory (A) stimulus, or a bimodal audio-visual (AV) stimulus corresponding to the simultaneous presentation of the two individual cues. The sequence of unimodal (auditory or visual) or bimodal trials is random. In response to each stimulus, the monkey has to touch a pad just above the starting pad. If the motor response is given within a certain time window, the animal will receive the reward (pellet) and the reaction time (RT) is measured.

In parallel, in the same monkeys, electrophysiological recordings were derived from single neurons in the auditory cortex and adjacent cortical zones in the posterior bank of the lateral sulcus. The extracellular recording of the neuronal activity is made with tungsten microelectrodes (Frederick Haer and Co) advanced with a hydraulic microdrive Narishige, attached to the recording chamber chronically fixed to the head of monkey. While the monkey performs the behavioral task, a dense cortical activity was recorded. The discrimination of neurons was done with the OpenEx software (Tucker-Davis-Technology (TDT), Florida, United States).

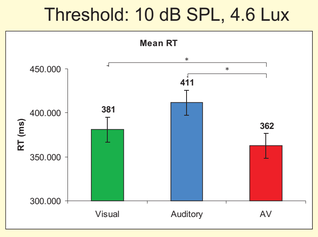


Location of the electrophysiological recording chamber on a lateral view of a macaque brain (left hemisphere). AS: arcuate sulcus, CeS: central sulcus, IPS: intraparietal sulcus, LaS: lateral (Sylvian) sulcus, PS: principal sulcus, STS: superior temporal sulcus.

Results

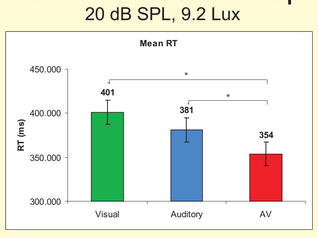
Behavioral data: Results from three representative conditions

Threshold: 10 dB SPL, 4.6 Lux



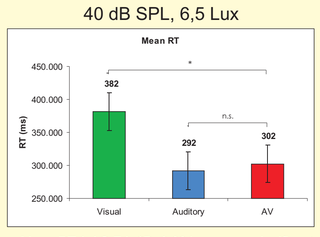
Mean RT (+/-S.E.). *P<0.001

20 dB SPL, 9.2 Lux



Mean RT (+/-S.E.). *P<0.001

40 dB SPL, 6,5 Lux



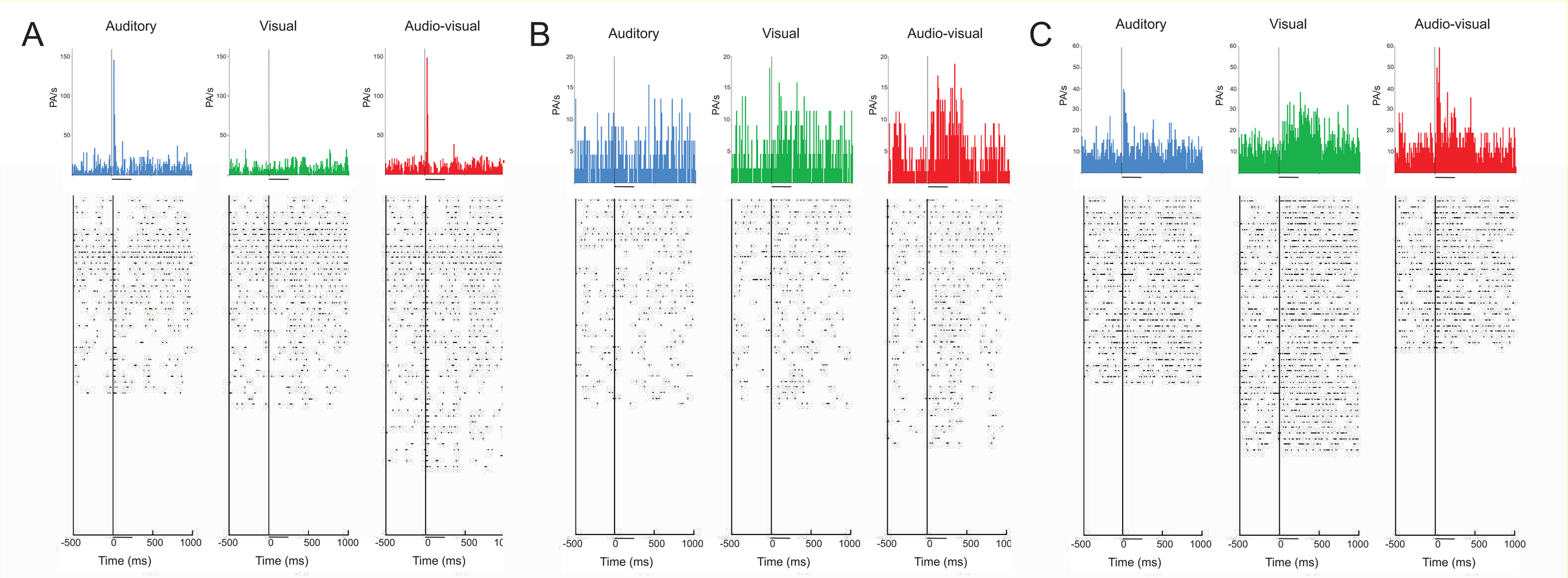
Mean RT (+/-S.E.). *P<0.001, n.s=non significant

These results show that mean reaction time for multisensory conditions at 20 dB SPL, 9.2 Lux and 10 dB SPL, 4.6 Lux (i.e near threshold) were significantly faster than those for the corresponding unisensory conditions ; however this is not the case at 40 dB SPL, 6.5 Lux.

Electrophysiological recordings

The activity of 308 cells was recorded extracellularly and we compared the mean spontaneous discharge rate (quantified in action potentials per second (PA/s)) with the mean discharge rate during the presentation of stimuli (A, V or AV) using a T-test (significant difference if $p<0.05$). At that step, the statistical analysis was conducted on 25 neurons. Examples of the activity of three neurons are presented in the Figures A, B and C.

ACTIVITY OF DIFFERENT NEURONS IN THE AUDITORY CORTEX DURING A DETECTION TASK OF AUDITORY, VISUAL AND AUDIO-VISUAL STIMULI



A. Example of activity pattern of a neuron recorded in the posterior bank of the LaS. The neuronal activity is represented in the form of “rasters displays”. Each point corresponds to an action potential and each line of points to a trial. Above the rasters the activity is represented for the cumulated trials in the forms of PSTHs (peri-stimulus time histogram) in PA/s with 10 ms bindwiths. The trial are aligned on stimulus onset A (left column), V (medium column) or AV (right column). Each stimulus lasts 250 ms, which is represented by the horizontal bar below the time scale. Like this one, 9 neurons (36% of the analyzed neurons) presented a response to A and AV stimuli which are significantly different from the reference activity (T-test, $p<0.05$).
B. Example of the activity of a neuron responding to AV stimuli presented in PSTHs and rasters forms. 4 neurons (16% of the analyzed neurons) presented a response only to AV stimuli which were significantly different from the reference activity (T-test, $p<0.05$).
C. Example of responses of a neuron to stimuli A, V or AV presented in PSTHs and rasters forms. We recorded this type of activity for 3 neurons (12%).
In addition, we recorded 3 neurons (12%) which responded exclusively to A stimuli, 2 neurons (8%) responded only to V and AV stimuli and 1 neuron (4%) only to V stimuli.

Conclusion

On the behavioral point of view, the bimodal condition had a significant facilitatory effect on reaction times and stimulus detection near threshold; this effect disappeared at high intensities.

On the electrophysiological point of view, different types of neuronal responses were observed. Some neurons responded only to auditory stimuli whereas, somewhat surprising, other neurons in the auditory cortex were influenced also by visual stimuli. Thus, the auditory cortex contains neurons which respond both to auditory and visual stimuli. These data confirmed other recent studies suggesting that multisensory convergence may occur at low cortical level.

Supported by SNF (3100-110 005-EMR)