Stimulus anticipation in following rhythmic acoustical patterns by tapping [1]

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Summary. Subjects followed rhythmic acoustical sequences by finger-tapping. Tapping onset preceded stimulus onset by a value close to 30 ms. It is suggested that this temporal difference might correspond to one cycle of a hypothetical timing mechanism in the brain which has been observed with other experimental paradigms.
Key words. Brain timing; rhythmic acoustical stimulation; stimulus anticipation.

Following rhythmic acoustical patterns by finger-tapping is characterized by a systematic error in synchronization; i.e., responses occur in advance of the stimulus with an anticipation interval close to 30 ms [2–6]. The neural basis of this phenomenon is still unclear. In the light of findings on the significance of temporal quanta and neuronal oscillations in brain timing [7–13], one possible explanation is that motor responses during repetitive tasks are shifted by about one temporal unit, or possibly by multiples of such a unit, prior to the onset of the stimuli. The aim of the present experiments was to test this hypothesis further.

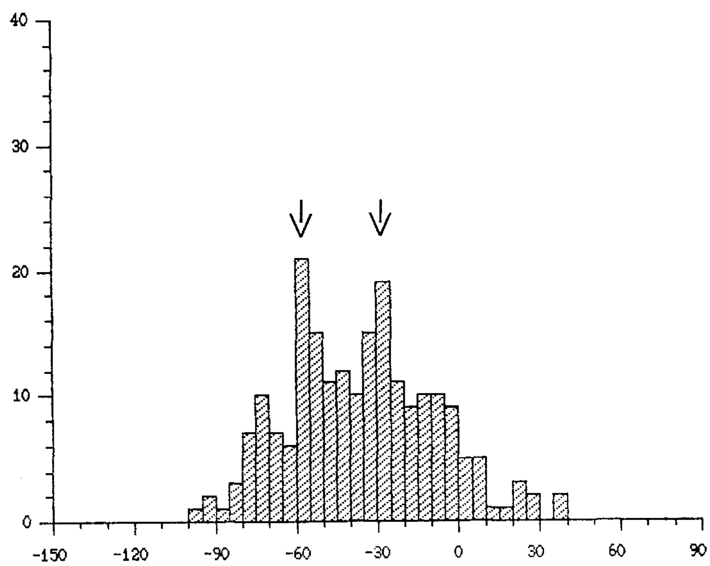
Material and methods

An IBM PC-AT computer was used to generate stimulus sequences which consisted of repetitive acoustical patterns composed of four tones, the first (accentuated) lasting 200 ms and the other three lasting 100 ms each, with intervals between tone onsets of either 500 ms (sequence-condition 1) or 700 ms (sequence-condition 2). Each sequence consisted of 55 consecutive patterns following each other without interruption for about 2–3 min. The subjects listening to the stimuli presented through headphones had to tap a response key with their index fingers in synchrony with the stimuli. The pitch of the tones was 262 Hz. Experiments were performed with 10 subjects. Time intervals corresponding to the difference between the onset of tones and the onset of key-touching were recorded and then analyzed.

Results and discussion

Anticipation of the onset of stimuli by the tapping response was a regular finding, as was reported previously. The average values for the whole group of anticipatory intervals with standard deviations, before the consecutive tones in patterns, are given in the table. The average anticipation intervals are all close to 30 ms. The variation around the mean values is, however, quite large. The question is whether, in spite of the large variability, the anticipation interval of approximately 30 ms corresponds to the hypothetical time quantum of the same duration which has been described by other experimental paradigms [7, 8, 10, 11].

It was observed that individual anticipatory interval histograms were often bi- or even multi-modal. One such example is given in the figure. As can be seen, there was a tendency in this subject to anticipate stimulus occurrence either by an interval close to 30 ms or one close to 60 ms. This was a regular finding in many subjects. Some other subjects showed response peaks close to 0 ms or to 30 ms. The multimodalities with an intermodal distance close to 30 ms, and the average anticipation interval close to 30 ms, support the notion that sensorimotor synchronization is controlled by a discrete temporal mechanism. The large variabilities observed (see table) using standard statistical techniques (arithmetical mean and standard deviation) are due to the fact that the underlying data-generating mechanism is apparently of a discontinuous nature, creating response preferences within different temporal windows. This leads to a spread of response values along the time axis. It is worth mentioning that the subjects were not aware of their systematic anticipatory error during synchronization. Even those subjects who knew about their anticipatory strategy could not prevent it voluntarily.



Histogram of stimulus anticipation in an experiment on sensorimotor synchronization. Abscissa: Anticipation time (negative values) in ms. Ordinate: Number of trials.

Anticipatory intervals (average values with standard deviation)

Tones in pattern	Before 1st tone	Before 2nd tone	Before 3rd tone	Before 4th tone
Sequence-condition 1 (500 ms intertone interval)	– 32.6 (± 36.7)	– 31.8 (± 38.4)	– 30.4 (± 35.2)	– 32.3 (± 34.8)
Sequence-condition 2 (700 ms intertone interval)	– 28.6 (± 37.3)	– 30.4 (± 39.4)	– 36.9 (± 42.6)	– 34.1 (± 38.4)

Minus sign means tapping onset precedes stimulus onset. For details see text.

The acoustic system is capable of differentiating much shorter time intervals between tones than 30 ms[14]. It is therefore obvious that the anticipatory error in following rhythmic stimuli is not caused by functional limitations of hearing. Instead, it is apparently related to temporal programming of a highly automatized, stereotypically repeated sequence of simple and probably ballistic movements. Because the response is anticipatory it is obviously not related to the stimulus proper but to the preceding stimulus, 500 or 700 ms earlier. As there is no difference in anticipation for the two interstimulus conditions (see table), the discrete temporal advance by approximately 30 ms is embedded in a higher order temporal control mechanism. Thus, not only temporal control in the perceptual domain, but also in the sensorimotor domain appears to be organized in a hierarchical way[15].

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Gustatory sensitivity of an anuran to cantharidin[1]

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Summary. Glossopharyngeal nerve stimulation of the bullfrog, *Rana catesbiana,* revealed responsiveness to low levels of cantharidin (1.3×10^{-6} M), providing a first demonstration of neural gustatory sensitivity of an animal to this defensive chemical from blister beetles (Meloidae).
Key words. Cantharidin; taste; glossopharyngeal nerve; Amphibia; Meloidae.

Cantharidin, the active principle of 'Spanish Fly', is one of the oldest-known poisons of insect origin[2]. Present as a defensive agent in the blood of blister beetles (family Meloidae) at concentrations in the order of 10^{-1} to 10^{-3} M, it is a strong feeding deterrent to ants and carabid beetles[3], and toxic to many vertebrates[4]. Nonetheless, several invertebrates[3,5], as well as vertebrates such as Japanese quail[6], armadillos[7], and a number of Amphibia[8,9], are able to eat blister beetles with apparent impunity. We here present evidence that in one known predator of blister beetles, the bullfrog *Rana catesbiana*[9], the ability to consume these insects is not attributable to an inability to taste cantharidin. We have shown this frog to have a high neural gustatory sensitivity to this compound, a capacity not previously demonstrated for an animal.

The experiments were carried out on 5 wild-caught bullfrogs (Ithaca, New York; body mass 48 ± 14 g). Each was anesthetized (10% aqueous urethane, intraperitoneal, 20 mg/kg b.wt), placed ventral side-up with the