Auditory modulation of tactile taps perception

Jean-Pierre Bresciani[1], Marc Ernst[1], Knut Drewing[1], Guillaume Bouyer[2], Vincent Maury[2], Abderrahmane Kheddar[2]

[1] Max Planck Institute for Biological Cybernetics, Spemannstr. 38, D-72076 Tübingen, Germany
[2] Laboratoire Systèmes Complexes, CNRS Université d'Evry Val d'Essonne, 40 rue du Pelvoux, 91020 Evry Cedex, France

Abstract. We tested whether the tactile perception of sequences of taps delivered on the index fingertip can be modulated by sequences of auditory beeps. In the first experiment, the tactile and auditory sequences were always presented simultaneously, and were structurally either similar or dissimilar. In the second experiment, the auditory and tactile sequences were always structurally similar but not always presented simultaneously. When structurally similar and presented simultaneously, the auditory sequences significantly modulated tactile taps perception. This automatic combination of "redundant-like" tactile and auditory signals likely constitutes an optimization process taking advantage of multimodal redundancy for perceptual estimates.

Introduction

Our everyday interactions with the environment provide us with a continuous stimulation of our different sensory channels. The central nervous system (CNS) has thus to deal with a pool of multimodal signals providing information of different nature concerning body/environment relationship. In many cases, the occurrence of a specific value of the signal in one sensory modality is accompanied by a "corresponding" specific signal in one or more other modalities. For instance, when knocking on a door, one gets congruent visual, tactile and auditory feedback, this feedback being specific to the characteristics of the action (e.g., number of times one knocked, delay in between two knocks, knocking force's intensity). Several psychophysical experiments suggested that these "redundant-like" sensory signals are automatically co-registered to derive a coherent unified percept of the presented stimuli [1-7]. In line with this, the present contribution tested whether "redundant-like" auditory and tactile signals are combined for tactile taps perception. More specifically, we tested whether the perception of tactile sequences of taps (2 to 4) delivered on the index fingertip can be modulated by simultaneously presented sequences of 'to-be-ignored' auditory beeps when the number of beeps differs (less or more) from the number of taps.

Methods and results

The experimental set-up is schematically represented on the Figure 1.

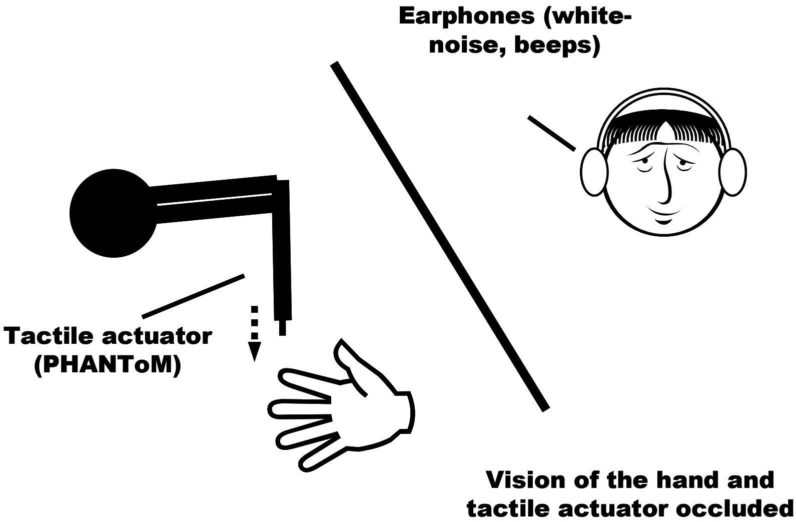

Fig. 1. Experimental set-up

In the first experiment, the auditory and tactile sequences were always presented simultaneously. Five auditory conditions were associated to the presentation of the tactile sequences: 'No Beep' (baseline performance for tactile perception), 'One Beep Less' (# beeps = # taps-1), 'same amount' (# beeps = # taps), 'One Beep More' (# beeps = # taps+1), and 'Control Beep' (unique long beep structurally dissimilar to the brief taps). Each tap lasted 20 ms and the delay between the onsets of two successive taps was 135 ms. Each beep lasted 50 ms and the delay separating the onsets of two successive beeps varied so that the onsets of the first and last beeps coincided with the respective onsets of the first and last taps. This first experiment was designed to determine

1) whether task-irrelevant auditory stimuli can modulate tactile taps perception and 2) to assess the importance of structural similarity for a modulation to occur.

As showed in Figure 2a, the perceived number of tactile taps was significantly (ANOVA) influenced by the simultaneous presentation of to-be-ignored auditory stimuli. Indeed, the perceived number of taps not only depended on the actual number of delivered taps [$F(2, 30) = 448.11$, $p < .001$], but also on the number of simultaneously presented auditory beeps [$F(4, 60) = 24.53$, $p < .001$]. This auditory modulation of tactile taps was observed for all tactile conditions, and very consistent across subjects (elicited in 13 subjects out of 16). However, when subjects were presented with an auditory stimulus that was structurally dissimilar to the tactile sequence (Control Beep), the perceived number of taps did not significantly differ from the conditions where no beep was presented or where the number of beeps was identical to the number of taps (see Figure 2b).

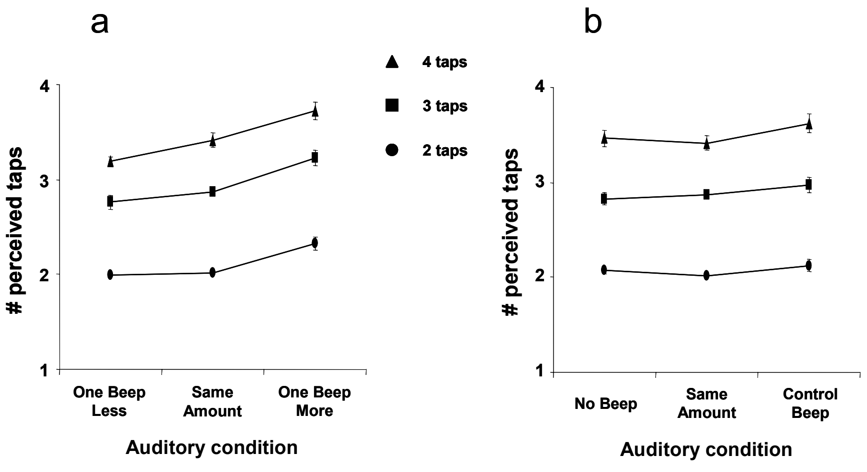

Fig. 2. Perceived number of taps as a function of the number of simultaneously presented beeps

In the second experiment, we tested whether simultaneity between auditory and tactile stimuli was necessary for a combination to occur. The sequences of beeps were always structurally similar with the taps sequences, but the timing between auditory and tactile sequences was systematically varied. For some timing conditions, there was no temporal overlap between the auditory and tactile sequences, the

auditory sequence being presented before the beginning or after the end of the corresponding tactile sequence.
The Figure 3 shows that the auditory modulation of tactile perception is dependent on the simultaneity between the stimuli presented in the two modalities. As in the first experiment, an auditory modulation of tactile perception was observed when the auditory and tactile sequences were presented simultaneously [$F(3, 45) = 17.858$, $p < 0.001$]. This modulation was weaker when the auditory stimuli was presented just before the beginning [$F(3, 45) = 4.08$, $p < 0.05$] or just after the end of the tactile sequences [$F(3, 45) = 4.776$, $p < 0.01$], and it completely vanished with a 200 ms gap between the auditory and tactile sequences.

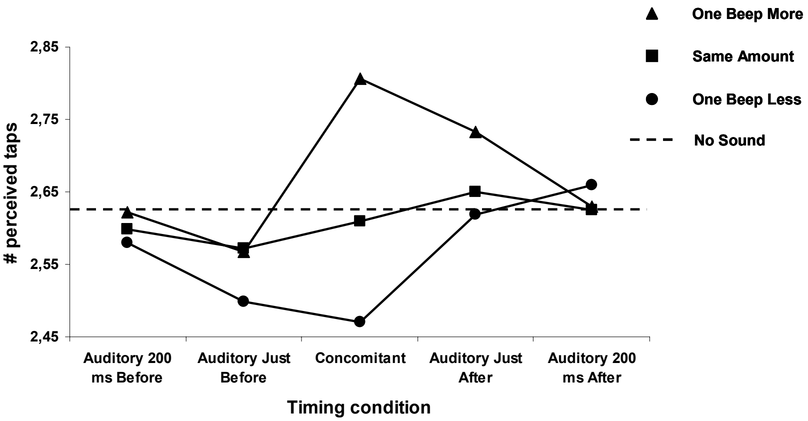

Fig. 3. Perceived number of taps as a function of the number of beeps for different "sequences onset asynchronies"

Conclusion

When presented with "redundant-like" (i.e. structurally similar, presented simultaneously) auditory and tactile signals, the CNS tends to automatically combine them. This likely results from the fact that the matching between co-occurring multimodal signals is very consistent across our everyday experience, so that the CNS can learn to co-register sets of redundant sensory signals and identify every single set as elicited by the same unique event or stimulus. Because multimodal cues reduce the variance of perceptual estimates [8-9] and enhance stimulus detection [10-11], such automatic combination of redundant-like sensory signals can be conceived as an optimization process.

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