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ORIGINAL ARTICLE/ARTICLE ORIGINAL

Integration of visual and haptic informations in the perception of the vertical in young and old healthy adults and right brain-damaged patients

Perception de la verticale chez des adultes sains jeunes et âgés et des patients avec lésion cérébrale droite : intégration des informations visuelles et haptiques

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Summary
Objective. — Multimodal perception raises the issue of sensory integration. The aim of this study is to assess whether the visuo-haptic subjective vertical could be predicted from the visual and haptic unimodal performances, according to a Bayesian model, which optimizes the reliability of the multimodal estimate. The limits of the model were assessed by evaluating the impact of aging, cerebral damage and spatial deficits.

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Method. — Young and older healthy participants, as well as patients with a right hemisphere lesion, suffering from spatial neglect or not, had to align a rod with the gravitational vertical in the visual, haptic and visuo-haptic modalities.
Results. — Visuo-haptic subjective vertical was correctly predicted by the model in healthy participants, as well as in patients in spite of different performances. An anticlockwise deviation of the subjective vertical was observed in the neglect group whatever the experimental conditions. By contrast, no deviation was observed in both non-neglect and healthy groups, for the visual and the visuo-haptic modalities. Nevertheless, the haptic subjective vertical was deviated, anticlockwise in the non-neglect patients and older healthy adults, and clockwise in the young healthy adults. Moreover, the variance was the smallest in the bimodal condition.
Conclusion. — The integration of visual and haptic signals appeared to obey a Bayesian model optimizing the reliability of the multimodal estimate. This holds true despite of aging, brain damage or visuospatial disorders. Regarding the perception of the vertical, multisensory integration does not seem thus to depend only on right posterior cortical areas.

MOTS CLÉS
Verticale subjective ;
Intégration visuo-haptique ;
Lésion cérébrale droite ;
Négligence spatiale ;
Âge

Résumé
Objectif. — La perception multimodalitaire pose la question de l'intégration sensorielle. Le but de l'étude était de vérifier si la verticale subjective visuo-haptique pouvait être prédite à partir des performances unimodalitaires, selon un modèle bayésien optimisant la variabilité de l'estimation multimodalitaire. Les limites du modèle ont été testées en évaluant l'influence de l'âge, de lésions cérébrales ou de troubles visuospatiaux.
Participants. — Des participants jeunes et plus âgés, ainsi que des patients porteurs d'une lésion hémisphérique droite, souffrant d'une négligence spatiale ou non, devaient aligner une barre avec la verticale gravitaire dans les modalités visuelles, haptiques et visuo-haptiques.
Résultats. — Les performances en modalité visuo-haptique étaient proches des prédictions du modèle, chez les participants sains comme chez les patients, malgré les différences de verticales subjectives. Chez les patients négligents, la verticale subjective était déviée dans les trois modalités. Chez les patients non négligents et les participants sains, elle n'était déviée que dans la modalité haptique, dans le sens anti-horaire chez les patients non négligents et les adultes sains plus âgés, et dans le sens horaire chez les jeunes adultes sains. Par ailleurs, la variabilité la plus faible était observée dans la modalité visuo-haptique.
Conclusion. — L'intégration des informations visuelles et haptiques paraît obéir à un modèle bayésien optimisant la variabilité de l'estimation multimodalitaire, même chez des personnes vieillissantes, souffrant d'atteintes cérébrales ou de troubles visuospatiaux. Concernant la perception de la verticale, l'intégration multisensorielle ne semble donc pas dépendre de l'intégrité des aires corticales postérieures droites.

Introduction

Perceiving the spatial properties of our environment is essential for regulating our interactions with the objects that compose it. Some of these properties are perceived by one sensory system only while other properties can be perceived by different sensory systems (see [24]). For example, the size of an object can be estimated from visual signals only, or from haptic signals, i.e. ''inputs from receptors embedded in the skin, as well as in muscles, tendons and joints'' [17]. It can eventually be estimated by combining these two sensory signals. In the case of multisensory perception, the use of different signals raises the question of the combination principle used by the nervous system to take into account the non-equivalent nature and variability of the information provided by each sensory system. In the early sixties, Rock and Victor [24] were already aware of this issue and tested how the size of objects was perceived when visual and haptic information conflicted. In this study, participants watched the object through a mirror so that it appeared, for instance, visually as a rectangle but haptically as a square. The results showed that they systematically based their estimation of the size on the information conveyed by the visual system, as if they were ignoring the haptic information, a phenomenon called ''visual capture'' [24]. In another study, ''haptic capture'' was found in conditions where visual information was degraded [11]. Later, Welch and Warren [32] suggested that, in case of perceptual conflict, the less uncertain sensory modality is generally used to estimate objects' physical properties.

Ernst and Banks [3,4] proposed a more general model of multimodal perception where all the available sensory signals are used, each being weighted according to its reliability, in the final perceptual estimate. It is to note that, in this view, the capture phenomenon occurs when one modality has a much higher reliability than the others. In the study of Ernst and Banks [4], the size of an object was estimated on the basis of visual (V), haptic (H), or visuo-haptic