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Everyday use of the computer mouse extends peripersonal space representation

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ABSTRACT

Auditory and tactile stimuli are integrated within a limited space around the body to form an auditory peripersonal space (APPS). Here we investigate whether the APPS representation around the hand can be extended through the use of a common technological tool such as the computer mouse. When using a mouse, an action occurring in the space around the hand has a distal effect in the space defined by the computer screen; thus, the mouse virtually links near and far space. Does prolonged experience with the mouse durably extend APPS representation to the far space? We examined 16 habitual mouse users to determine whether a sound presented near the right hand or near the computer screen affected reaction times to a tactile target at the hand. When subjects sat in front of the computer, without holding the mouse, they responded faster to tactile stimuli when sounds were presented near the hand rather than near the screen, consistent with a normal segregation of APPS around the hand. In contrast, when subjects either actively used or even passively held the mouse, the difference between the effects of near and far sounds disappeared, thus showing an extension of the APPS toward the far space. This effect was selective for the effector used to operate the mouse: if tactile stimuli were presented on the left hand, rarely used to act upon the mouse, a sound presented near the hand speeded up reactions times when subjects both held and did not hold the mouse in their left hand.

1. Introduction

The body is the focus of certain spatial representations. Converging evidence from neurophysiology, neuropsychology and psychology suggests that spatial representation is not uniform, but that there are multiple, modular representations of space, with specific characteristics and functions; the body is at the centre of such representations. To simplify, we might distinguish at least three spatial representations originating from the body (see, e.g. Rizzolatti, Fadiga, Fogassi, & Gallese, 1997): the body space (see de Vignemont, this issue), the space far from the body, i.e. not reachable by a simple movement of the arm, named extrapersonal space, and the space immediately surrounding the body, i.e. peripersonal space (PPS), which is the topic of the present paper.

Several lines of evidence support the existence of a specialized brain system that specifically represents the PPS. Neurophysiological studies in monkeys described multisensory neurons in subcortical and cortical fronto-parietal regions which respond both to tactile stimuli delivered on a given body part (namely the head, arm, trunk) and to visual stimuli presented close to the same body part. Importantly, these neurons show null or lower responses when visual stimuli are presented far (at more than about 30 cm) from the body part where the tactile receptive field is located (Colby, Duhamel, & Goldberg, 1993; Duhamel, Colby, & Goldberg, 1998; Fogassi et al., 1996; Graziano, Yap, & Gross, 1994; Rizzolatti, Scandolara, Matelli, & Gentilucci, 1981). Similar response properties have been described for premotor (Graziano, Reiss, & Gross, 1999) and parietal (Schlack, Sterbing-D'Angelo, Hartung, Hoffmann & Bremmer, 2005) neurons sensitive to tactile stimuli administered on the head and auditory stimuli presented near the head. Thus, these neurons integrate tactile information on the body with visual and auditory information presented close to the body.

Similar integrative properties of PPS in humans have been described in neuropsychological studies conducted on brain damaged patients with cross-modal extinction. In these patients, the perception of contralesional tactile stimuli was affected by concurrent ipsilesional visual or auditory stimuli, and this effect is much stronger when visual or auditory stimuli are presented close to the patient's body rather than far apart, in the extrapersonal space (Di Pellegrino, Làdavas, & Farnè, 1997; Farnè & Làdavas, 2000). The near-far modulation of cross-modal extinction has been considered

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the behavioral hallmark of multisensory integrative systems coding PPS in humans (see Làdavas & Farnè, 2004b; Làdavas & Serino, 2008 for reviews).

An important property of PPS is the possibility of being modified as a function of experience. We can use a tool to reach portions of the extrapersonal space, and, consequently, to make reachable the unreachable space. This activity has been shown to extend the representation of the PPS. For instance, visual peripersonal space (VPPS) around the hand extends after a training that consists in using a rake to reach and collect objects placed far from the body, both in monkeys (Iriki, Tanaka, & Iwamura, 1996; Ishibashi, Hihara, & Iriki, 2000) and in humans (see also Farnè & Làdavas, 2000; Holmes & Spence, 2005; Ishibashi, Obayashi, & Iriki, 2004; Làdavas & Serino, 2008; Làdavas, 2002; Maravita & Iriki, 2004; Maravita, Husain, Clarke, & Driver, 2001 for reviews). In order to extend VPPS actual use of the tool is necessary, because no extension occurs if the tool is passively held in the subjects' hands (Ishibashi et al., 2004; Làdavas & Farnè, 2006). Interestingly, the extension of peripersonal space after tool-use has been described by previous studies as lasting only briefly, because multisensory VPPS contracts to the pre-tool-use level several minutes after the end of training. However, tool-use is quite a common experience in everyday-life, and indeed there are some subjects who habitually and functionally use a tool to interact with extrapersonal space, such as blind people who use a cane to navigate in their daily environment. A recent study by our group investigated audio–tactile integration in the space around the hand and in extrapersonal space in order to measure the extension of the auditory peripersonal space (APPS) in blind cane users and in a control group of sighted, blindfolded, subjects (Serino, Bassolino, Farnè, & Làdavas, 2007). The results showed that while in sighted subjects the APPS is normally limited around the hand, in blind subjects it is immediately extended as soon as they hold their cane, even without any active momentary use of the tool. These findings suggest that the long-term experience with the cane in blind people produces a special and durably extended representation of APPS, which can be dynamically and functionally engaged depending on contextual demands. As far as we know, results from Serino et al. (2007) are the first demonstration of a durable extension of PPS representation. However, that study was carried out in a particular population of subjects, using a quite special tool.

The aim of the present work is to study whether sighted subjects who regularly use a common everyday-life tool, such as the computer mouse, have a durably extended PPS representation. To this end, we investigated the properties of APPS representation around the hand in subjects using the computer mouse everyday. The computer mouse can be conceived as a common tool linking peripersonal and extrapersonal space: it is used in the space near the hand but has an effect in far space, on the computer screen. Thus, a long-term experience with the computer mouse might durably extend the integrative space surrounding the hand. To test this hypothesis, we conducted two experiments on subjects who use the computer mouse for several hours per day *with their right hand*. In a first experiment, we measured the extension of APPS around the right hand, to study the effect of long-term experience of mouse-use. In a second experiment, we measured the extension of the APPS around the left hand in order to test whether any change in PPS representation was really induced by long-term mouse-use experience and therefore was selective for the hand used to operate with the mouse.

2. Experiment 1

We selected sixteen subjects who use a computer mouse everyday for work. In order to measure the extension of the auditory peri-hand space, we used the same task as in Serino et al. (2007): participants sat in front of the computer screen and were requested to verbally respond as fast as they could to a tactile target administered on their right hand, while concurrent task-irrelevant sounds were presented either near the stimulated hand (near sounds) or 70 cm away from the hand (far sounds). Previous studies have shown that auditory stimuli can affect the perception of tactile stimuli, both in term of detection ability (e.g. Ro, Hsu, Yasar, Elmore, & Beauchamp, 2009) or reaction time (e.g. Zampini, Torresan, Spence, & Murray, 2007), and that these audio–tactile interactions truly rely on a multisensory integrative mechanism and not on a simple summation of unisensory signals (Murray et al., 2005). The present paradigm was designed to study how the spatial distribution of auditory stimuli influences tactile processing. To this aim, mean reaction times (RT) to the tactile target were compared when "near" or "far" sounds were administered. A faster response to the tactile target associated with near rather than with far sounds show a specific audio–tactile interaction near the body and thus is considered as an index of segregation of APPS around the hand (Làdavas & Serino, 2008; Serino et al., 2007). The experimental task was conducted while participants were instructed to attend to visual stimuli presented on the computer screen. The differential effect of near and far sounds on tactile detection was compared in 3 different experimental conditions: the "No-mouse condition" (baseline condition), the "Passive mouse-hold condition" and the "Active mouse-use condition". In the first condition, participants had to verbally detect the presence of a weak tactile stimulus delivered on their right hand, placed palm-down on the table, immediately after the presentation of a visual stimulation on the computer screen (see below); in this condition subjects did not hold the computer mouse. The "Passive mouse-hold condition" was similar, but now participants held the mouse in their stimulated hand. This condition was designed to investigate whether an extended representation of APPS might be automatically evoked when subjects held the computer mouse without actually using it. In the "Active mouse-use condition", subjects were requested to use the mouse to act on the visual stimuli presented on the computer screen (see below); thus the mouse was actually used to interact with the far space.

In the "No-mouse condition", a segregation of APPS is expected near the hand: RTs associated to the near sound should be faster than RTs associated to the far sound. In the "Active mouse-use condition" this segregation should be abolished, or reduced, due to the extension of the peri-hand space towards the far space: the difference in RTs associated with near and far sounds should be absent, or lower, than in the "No-mouse condition". A similar reduction in the near-far RT difference should occur during the "Passive mouse-hold condition", if we accept the hypothesis that holding the mouse activates a mental representation of action linked to the mouse and this is sufficient to extend the APPS.

2.1. Methods

2.1.1. Subjects

Sixteen healthy computer-users (8 female) participated in the study. Subjects' mean age was 24 years (SD = 1.42, range: 22–27 years). All participants had normal vision, hearing and touch. At the end of the experiment, subjects filled in a questionnaire concerning their everyday-life experience and their experience of the computer mouse.

Data from the filled questionnaire demonstrated that the participants use the computer mouse for almost 5 h per day (mean = 4.75 h, SD = 3.80), and have been using the mouse for almost 10 years (mean = 9.75, SD = 3.60).

All participants were right-handed and used the computer mouse with their right hand. Subjects gave their informed consent to participate in the study, which was performed with approval of the local ethics committee and in accordance with the Declaration of Helsinki.

2.1.2. Materials

Tactile stimuli were delivered by two constant-current electrical stimulators (DS7A, Digitimer, Hertfordshire, United Kingdom), via two pairs of neurological electrodes (Neuroline, Ambu, Ballerup, Denmark) placed on the dorsal face of the index finger. One pair of electrodes delivered weak stimuli, and the other pair delivered