Preattentive interference between touch and audition: a case study on multisensory alloesthesia

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Received 24 February 2005; accepted 14 March 2005

Alloesthesia is a rare clinical condition that corresponds to a spatial disorder of stimulus localization, in which patients experience a given stimulus on the side opposite to the side of stimulation. Whereas it has been mostly described for unisensory stimulations, evidence of multisensory alloesthesia is only anecdotal. Here, we investigated a case of multisensory auditory–tactile alloesthesia. Our data suggest that auditory–tactile integration and multisensory alloesthesia not only depend on attentional mechanisms, but also on somatotopic preattentive mechanisms. *NeuroReport* 16:865–868 © 2005 Lippincott Williams & Wilkins.

Key words: Alloesthesia; Human; Multisensory; Preattentive; Somatotopic; Space

INTRODUCTION

The integration of multisensory target locations is essential for providing a unified spatial perception of the world around us. In everyday life, multisensory interactions do not always improve but may also disturb spatial perception [1]. After unilateral brain damage (mostly right-sided), patients may fail to detect bilateral simultaneous stimuli by systematically omitting stimuli applied on the contralesional side (extinction [2]). More rarely, rather than extinguishing the contralesional stimulus, some patients may perceive the latter at an unstimulated location of the ipsilesional side (alloesthesia [3–6]). Until now, this intriguing phenomenon has almost always been observed from the contralesional to the ipsilesional side in unisensory stimulation (for touch [3–5], vision [4], audition [4]). Yet, extinction can also occur when the stimuli on opposite sides belong to different sensory modalities (e.g. multisensory audiotactile extinction [2,3,6]). One question is thus whether corresponding cases of 'multisensory alloesthesia' could occur in order to shed light on the functional mechanisms of alloesthesia.

We studied an 84-year-old right-handed woman, with a right frontoparietal lesion (Fig. 1), who systematically mislocalized sounds or touches from the contralesional (left) to the ipsilesional (right) space of her body when multisensory stimuli were simultaneously presented.

PATIENT AND METHODS

Patient report: An 84-year-old, right-handed woman with no neurologic antecedents was hospitalized at the neurology clinic of the Geneva University Hospital in January 2002 for falls due to a left hemisyndrome. The neurological examination revealed a moderate deficit in somatosensation in the left arm and leg (light touch, pinprick, joint position sense, palloesthesia) and a moderate weakness in the left arm and leg, which recovered within 2 weeks. Neither a visual field deficit nor an auditory deficit was detected. Diffusion-weighted imaging and T2-weighted imaging showed an ischaemic infarction at the junction of the right frontoparietal cortex (Fig. 1). The neuropsychological examination did not show any deficit except a moderate left extrapersonal neglect for bell cancellations, drawings and line bisections, and also a mild dysexecutive syndrome. No sign of right–left disorientation, asomatognosia, astereognosis, agraphesthesia or personal neglect was observed. Assessment of unisensory extinction revealed strong left tactile extinction (face: 0/10 correct, hands: 2/10 and feet: 0/10), strong left auditory extinction (0/10 correct) and mild left visual extinction (8/10 correct). Detection of unilateral stimuli was flawless on both sides in every modality. Assessment of multisensory extinction did not show any deficit between vision and audition (10/10 correct). However, there was mild multisensory extinction between vision and touch (on face: 9/10 correct, hands: 6/10, feet: 6/10), and strong multisensory extinction between audition and touch (0/10 correct). Surprisingly, while being tested in this latter condition, the patient spontaneously perceived the left-sided stimulus on the right side (multisensory alloesthesia), occasionally even by pointing to her right ear after left auditory stimulation or by moving her right hand after left tactile stimulation. To elucidate the mechanisms involved in multisensory alloesthesia, several experimental and

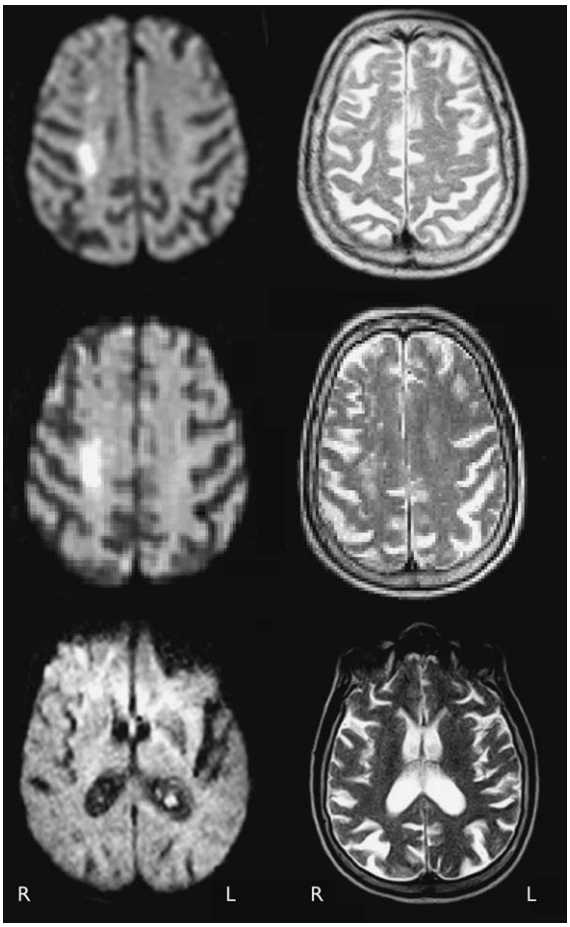

Fig. 1. Lesion location as defined by magnetic resonance imaging. Diffusion-weighted imaging (left) and T2-weighted imaging (right) showing ischaemic infarction at the junction of the right frontoparietal cortex.

neuropsychological sessions were conducted with auditory–tactile stimuli.

Experimental design: During all experimental sessions, conducted in conformity with the Declaration of Helsinki, the patient sat blindfolded on a chair and was instructed to keep her head straight. She was first instructed to attend either to the tactile (condition 1) or to the auditory (condition 2) modality in different blocks presented in a counterbalanced ABBA order. During each trial, one of four different stimulus types was presented: left touch/left sound, left touch/right sound, right touch/left sound, right touch/right sound. The patient's task was to report (1): the number of stimuli she perceived ('one', 'two' or 'none'), (2) the location of the relevant stimulus ('left', 'right' 'both' or 'absent') and, if present, (iii) the stimulated body part. In order to test any effect that touching different body parts may have on the localization of contralesional stimuli, tactile stimuli could be randomly applied to the face, hand or foot on each trial. Double *homolateral* stimulations served as control conditions to test the general ability of our patient to detect double stimuli, given that both relevant and irrelevant stimuli were applied to the same side (n=12). Catch trials, whereby the relevant stimulus was absent, were also administered in a random order along the stimulus sequence for allowing the control of any guessing strategy (n=10). Tactile stimulations consisted of light, brief touches applied with a thin stick. Auditory stimuli consisted of finger snaps at about a distance of 20 cm from the head.

RESULTS

Double simultaneous homolateral stimulations were flawless, suggesting that the patient was able to perceive double stimuli. Also, catch trials led to 100% correct performance, suggesting that wrong localization of contralesional stimuli occurred only when a contralesional stimulus was indeed present and was not the result of guessing. When double bilateral stimuli were given, the relevant stimulus was always reported. However, while relevant right-sided stimuli were always localized at the correct body side (72/72 correct trials), relevant left-sided stimuli were mostly reported as delivered to the right side (19/72 correct, 26%).

Notably, stimuli were mislocalized only from the left to the right side, while no right to left mislocalizations ever occurred. A statistical analysis of variance (ANOVA) on trials restricted to the relevant left-sided stimuli was performed using attended modality as a within-factor and the stimulated body parts as a categorical factor. Irrelevant right-sided stimuli in both modalities induced an illusory mislocalization of left-sided stimuli of the other modality (see Table 1). Yet, right-sided sounds more often 'captured' left-sided touches (5/36 correct; 14%) than right-sided touches 'captured' left-sided sounds [14/36 correct, 39%; $F(1,33)=16.2$, $p<0.001$].

In condition 1 ('touch-relevant'), multisensory alloesthesia was systematically observed whatever the body part involved in tactile stimulation (face: 0/1 correct; hand: 3/12 correct, 25%; foot: 2/12 correct, 17%). Planned comparisons with correction for multiple comparisons did not show any difference between stimulated body parts (face vs. hand: p=0.08, face vs. foot: p=0.24, hand vs. foot: p=0.56). Phenomenological analysis of these errors revealed systematic mislocalizations of the relevant left-sided tactile stimuli that were applied to lower body parts towards the right side of the face. Relevant left-sided touches applied to the hand were sometimes mislocalized towards the right hand (33%; single-sample t-test, p=0.08), but predominantly towards the right face (67%; single-sample t-test, p=0.004).

In the same way, relevant left-sided touches administered to the foot were predominantly mislocalized to the right face (70%; single-sample t-test, p=0.001; and only 30% to the right foot, single-sample t-test, p=0.08). Additionally, relevant left-sided touches applied to the face were always mislocalized towards the homologous right side of the face (100%). For 'right touch/left sound' stimulations, the patient perfectly detected relevant right-sided touches.

In condition 2 ('sound-relevant'), irrelevant right-sided touches significantly induced mislocalizations of left-sided sounds from left to right when they were applied to the face (0/12 correct) or hand (2/12 correct, 17%). Yet, no mislocalization of left-sided sounds was observed when irrelevant right-sided touches were applied to the foot (100% correct). For 'right sound/left touch' stimulations, the patient perfectly detected relevant right-sided sounds. Planned comparisons with correction for multiple comparisons revealed significant difference for irrelevant right-sided touches applied to the face and hand compared with foot stimulation ($p<0.001$).

Table I. Percent of correct spatial locations of relevant stimuli obtained in every condition with respect to the side of presentation (left or right) and the modality (tactile or auditory) of both simultaneous stimuli (relevant and irrelevant).

	Condition 1: 'attended touch'				Condition 2: 'attended sound'			
	Relevant left touch		Relevant right touch		Relevant left sound		Relevant right sound	
	Irrelevant left sound	Irrelevant right sound	Irrelevant left sound	Irrelevant right sound	Irrelevant left touch	Irrelevant right touch	Irrelevant left touch	Irrelevant right touch
Face	100%	0%	100%	100%	100%	0%	100%	100%
Hand	100%	25%	100%	100%	100%	17%	100%	100%
Foot	100%	17%	100%	100%	100%	100%	100%	100%
Mean	100%	14%	100%	100%	100%	39%	100%	100%

DISCUSSION

This case shows how pathological multisensory integration may affect the spatial coding of relevant left-sided sensory information leading to the condition of multisensory alloesthesia between audition and touch. To our knowledge, this is the first systematic report that alloesthesia may be found with stimuli from different sensory modalities. Interestingly, this phenomenon was coupled to some degree with multisensory extinction for the same sensory modalities. The patient's systematic *left to right gradient* can thus be attributed to an attention disorder affecting interhemispheric competition between specific kinds of multisensory (auditory–tactile) representations during double bilateral simultaneous stimulations, as previously hypothesized for extinction [2,3,6–8]. Indeed, similar competition never occurred between stimuli belonging to other sensory modalities (e.g. vision) or when both stimuli were delivered to the same side of the body. The specificity of this phenomenon for auditory–tactile double stimuli makes it unlikely that it is the result of a general response bias, whereby the patient tends to respond 'right' for any stimulus delivered to the left side. This suggests that in conditions of abnormal attentional resources, coherent integration between the neural representation of the body and its surrounding auditory space was disrupted. Notably, mislocalizations did not occur towards random ipsilesional positions but followed precise anatomical and spatial rules. Indeed, phenomenological analysis of allesthetic misperceptions revealed a systematic spatial distortion of tactile localizations from left-sided lower body parts towards the right side of the face. Left misperceived relevant acoustic stimuli were always reported at the location of the right ear, regardless of the position of the irrelevant right tactile stimulus.

More interestingly, mislocalization of left sounds occurred for right touches to only the face or hand, but not to the foot. This lets us conjecture that the coding of multisensory somatotopic information might occur before attentional selection is complete within one modality. Whereas mislocalization of stimuli on the face may be a consequence of some degree of 'auditory' capture of touch [1], their mislocalization at the homologous body site on the right side suggests that the correct position of the tactile stimulus on the left side was coded (at least to some extent) at an implicit ('preattentive') level, but then attributed to the wrong side. These findings thus reinforce the assumption that some multisensory integration can arise at a preattentive level to produce multisensory internal representations in which attention can be directed [7,9–12]. In addition, considering recent evidence of a perihead space for integrating auditory–tactile information [6,13], our results could also be interpreted as a preattentive modulation of multisensory integration within this peripersonal space. Indeed, the coding of a right-sided touch falling outside the perihead space (such as foot stimulation) did not interfere with the representation of a left-sided sound. Our data thus suggests that auditory–somatosensory integration may occur early in the auditory cortical hierarchy (i.e. in the auditory association cortex), as demonstrated in two recent functional neuroimaging studies [12,14]. Nevertheless, we delivered ipsilesional sounds at only the ear level (i.e. within the perihead space) and never outside the perihead space (i.e. in proximity of the hands or feet). We can thus not exclude the fact that – in addition to the assumed somatotopic preattentive mechanism – the location of the ipsilesional sound close to the face induced the patient's frequent mislocalizations towards her face. Further studies testing auditory–tactile alloesthesia for different sound locations inside and outside the perihead space seem necessary to distinguish between both mechanisms.

In conclusion, the systematic pattern of allesthetic mislocalizations and the selective absence of alloesthesia for some body parts suggest that alloesthesia depends not only on attention, but also on somatotopic preattentive mechanisms.

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Acknowledgements: This work was supported by The Swiss National Research Foundation grants (No. 3100-065096.01/2 and No. 3100-065232.01) and the Leenaards Foundation.