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# Multisensory integration for spatial orientation in trait anxiety subjects: absence of visual dependence

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**Summary** – Studies suggest a greater reliance on visual information for maintaining balance in anxious subjects. Nevertheless, links between this supposed preferred visual processing and spatial orientation have not yet been evaluated. Two groups of subjects differing in their level of trait anxiety were formed. Equipped with a head-mounted visual display, they learned a virtual corridor using passive translation but active rotation, both with normal and with two different conflicting sensory conditions. After two visual navigation trials in the corridor, they were blindfolded and asked to reproduce the same trajectory from memory. In addition, subjects drew a map of the remembered corridor. Anxious subjects were comparable to non-anxious subjects when asked to reproduce the trajectory from memory, but exhibited a deficit when drawing a map of the corridor they were in. The results do not support the hypothesis that anxious subjects use preferentially one type of sensory cue over another for spatial orientation, but instead manifest difficulties in constructing more global representations of space.

Anxiety / Multisensory integration / Navigation / Spatial memory / Virtual Reality / Humans

## INTRODUCTION

Numerous studies have tried to find a link between vestibular dysfunction and anxiety because of dizziness symptomatology that is common to the two diseases (see [1] for a review). Even if several studies have managed to point out some abnormalities of vestibular functioning in panic and agoraphobic patients, there is no consensus about the nature of the association between these disorders and the vestibular findings. Nevertheless, several studies have led to the observation that patients with agoraphobia, panic or space and motion discomfort (SMD) may have a problem with multisensorial integration: subjects with symptoms of

panic and agoraphobia are destabilized under conflicting sensory conditions while maintaining an upright posture [4,5,16]. Their apparent vestibular disorders may not concern low level vestibular functions such as those explored so far (e.g. vestibulo-ocular reflexes), but rather higher cognitive integration of vestibular self-motion signals contributing to spatial cognition, processes that involve structures such as the hippocampus and parietal cortex [2]. Spatial disturbances are common complaints in pathological anxiety, and particularly in the case of agoraphobia. Spatial cognition has rarely been studied in these patients, but a few studies have proved so far that such patients demonstrate a deficit in way-finding abilities and topographical repre-

sensation [6,7]. In particular, map-like representations that encode metric distance relationships in allocentric coordinates (world-centered) were inaccurate in panic agoraphobic patients [6].

In our study, we employed a dimensional- and symptom-oriented approach, which aims at linking psychiatry to the understanding of normal physiopathological processes. In this context, we chose to work on the basis of trait indices rather than on pathological ones, seeking processes, which could be of importance for the development of anxiety disorders linked to space. In order to increase the strength of the design of our study (see [3]) we selected two groups of subjects representing extreme scores on the State-Trait Anxiety Inventory [11]. As perceptual conflict situations have been exhibited as key features in anxious patients, we studied multimodal space representation in high and low trait anxiety subjects. We temporarily distorted the normal relationship between visual and idiothetic (vestibular, somato-sensory and motor-outflow) sensory information, and measured post-effects that occurred in selected perceptual-motor tasks. We applied a paradigm consisting of a 'memorized navigation' task allowing the study of the transformation of sensory information into an egocentric representation of the path used in the active reproduction of the movement, and into a more global, cognitive representation used in drawing a map of the remembered trajectory.

With this paradigm, we address the question of a proprioceptive or visual dominance for maintaining orientation in anxious individuals [4,12]. Indeed, if one sensory modality had greater dominance over another, one would expect that when reproducing the path with eyes closed, anxious subjects would reproduce either the idiothetic or the visual information, suggesting a greater after-effect for one information over the other. Moreover, we could observe at which level this dominance takes place by examining the cognitive representation of the path (drawings).

## SUBJECTS AND METHODS

### Subjects

Sixteen undergraduate students (mean age 21 years, S.D. = 2) were recruited on the basis of their trait anxiety score as assessed by the State-Trait Anxiety Inventory [11]. Two groups of eight participants were formed, according to their low (< 31, low trait anxiety or 'LTA' group) or high (> 50, high trait anxiety or

'HTA' group) scores on the trait anxiety scale of the STAI (four females, four males in each group). All subjects were right-handed. None of the subjects presented any history of neurological disease or vestibular impairment. Psychiatric interviews based on the Mini International Neuropsychiatric Interview [8] indicated that five students from the HTA group were actually sub-threshold according to the DSM-IV criteria for the following anxiety disorders: agoraphobia without history of panic disorder (one subject), general anxiety disorder (two subjects), social phobia (one subject) and current panic disorder (one subject). Subjects from the LTA group had no history of anxiety disorder nor did they meet the DSM-IV criteria for any psychiatric disorder. After complete description of the study to the subjects, written informed consent was obtained and subjects received a compensation of 50 French Francs for their time.

### Experimental procedure

Subjects were seated on a simple rotating chair and were immersed in a virtual corridor presented in a head-mounted visual display (VR4, Virtual Research Systems, Santa Clara, CA) (Fig. 1). Subjects moved passively forward along the corridors at a constant velocity imposed by the computer. When subjects arrived passively in the virtual world at a corner of the corridor they had to negotiate a specific turn by rotating actively their body in order to follow the trajectory of the corridor. Head orientation was sensed by an ultrasound tracker (Logitech, Fremont, CA) and the head angular position information was computed by software, which output the corresponding image to the display. Visual images were thus coupled with the movements of the subject (see [12] for a technical description of the hardware). The software did not allow subjects to cross the walls of the corridors, and therefore, in case of collision the trajectory slid along the walls. The simulated linear speed corresponded to the walking human locomotor range (ca.  $1 \text{ m s}^{-1}$ ). Subjects used their legs to turn around their axis, thereby receiving proprioceptive feedback both from the vestibular and kinesthetic senses.

Before the actual measurements started, subjects were given test runs in which they could get acquainted with the method for turning. After this, their task was to learn virtual corridors using passive translation but active rotation as described above. After two visual navigation trials in a given corridor (Navigation task),

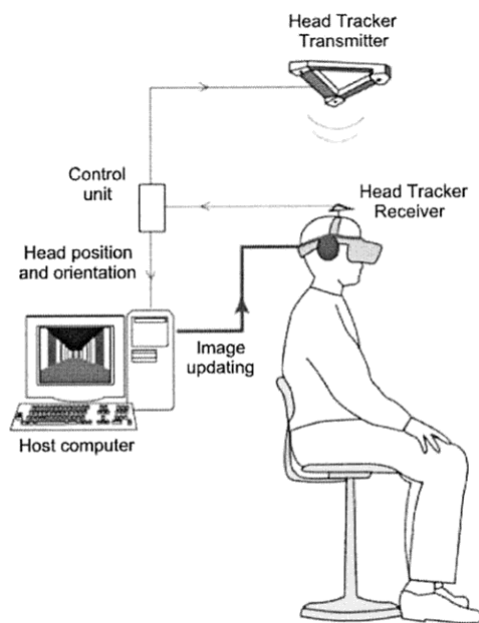


Fig. 1. Experimental set-up. The subject was seated on a chair that he could rotate. He was immersed in a virtual environment by means of a head-mounted display. The subject's head direction was sensed by an ultrasound system. Custom software took the head angular position information from the tracker and output the corresponding visual image.

subjects were blindfolded and asked to reproduce the trajectory through the corridor from memory by mentally visualizing the optic flow and actively rotating the body appropriately (Memorized navigation task). At the end of the experiment, they were asked to draw the last corridor they learned (Drawing task).

Three corridors (C1, C2, and C3) were used to complete the experiment. They were made of four straight segments connected with three angles (45, 90, 135°), combined differently in each corridor. The floor and the walls of the corridors were, respectively, structured with stripes and checkerboards in order to enrich the virtual environment. Colors of ceiling, walls and floor were different in each corridor.

Three visual conditions (one per corridor) were tested: normal, increased and decreased visual flow for angular rotation. In the two latter conditions, we introduced a sensory conflict between the visual information on the one hand and the somatic, motor-outflow and vestibular information on the other hand by changing the ratio  $r$  of visual scene rotation  $V$  to body rotation  $B$  ( $V = r \cdot B$ ). This ratio is normally 1 (normal visual flow). The

ratio was, respectively, 1.5 (increased visual rotation) and 0.66 (decreased visual rotation) in the two conflict conditions. For example, in the increased visual rotation condition, a body rotation of 90° would induce a rotation in the visual display of 135° ( $V = 1.5 \cdot 90$ ). This means that when the angle of the corner in the corridor was 90° the subjects would have to turn the chair by 60°. In the decreased visual rotation condition, if subjects rotated the chair by 90° they saw in the corridor a rotation of 59.4°, and thus had to turn the chair by 136° to have a 90° rotation in the visual display.

The computer recorded the virtual trajectory of the path followed by the subject in the corridor. The amplitude and direction of each turn in the trajectory were computed. Drawings were attributed a score according to the following criteria: correct total number of turns, direction and amplitude of each angle, reproduction of three angles each of different amplitude. A total of ten signified a perfect correspondence between the actual map of the virtual corridor and the schematic representation drawn by the subject. Drawings were evaluated by two judges blind to the group to which the subject belonged.

## RESULTS

### Navigation and memorized navigation tasks

Both HTA and LTA participants navigated accurately in the virtual environment. A large variability in memorized navigation was observed for all subjects. Whereas both groups of subjects were comparable in terms of reproduction of angle amplitude, reproduction of direction was less accurate in HTA group (six HTA subjects did a direction error in at least one turn of one of the corridors, five out of six in conflict conditions, see [Table 1](#)).

### Effect of visual conditions

Surprisingly, nobody noticed any incoherence between real whole-body rotation and rotation in the virtual corridor in either conflict condition (increased or decreased visual rotation). However, the characteristics of memorized navigation exhibited a difference between having normal or conflicting visual flow (see [Table 1](#)). In the increased visual rotation condition, vision appeared to have a greater influence on angular reproduction, whilst in the decreased visual rotation condition, idiothetic information seemed to predominate.

Table 1. Absolute amplitude of angular reproduction in degrees, for each corridor (C1, C2, and C3), and according to the instructed angle in the visual condition (45, 90 and 135° angles). Between brackets are written the ideal amplitudes of movements corresponding to the imposed visual stimulus (differing according to the visual condition). DE represents the number of errors in direction made when reproducing or drawing the angles

Measure	HTA subjects			LTA subjects		
	Mean	S.D.	DE	Mean	S.D.	DE
<i>C1—Normal visual flow</i> <sup>a</sup>						
45	62	34	1	70	19	0
90	99	21	0	90	17	0
135	156	30	0	151	33	0
<i>C2—Increased visual rotation</i> <sup>a</sup>						
45 (30)	42	27	2	50	13	0
90 (60)	86	28	2	88	15	0
135 (90)	99	52	2	108	29	0
<i>C3—Decreased visual rotation</i> <sup>a</sup>						
45 (68)	77	50	2	74	25	0
90 (136)	112	52	0	117	19	0
135 (204)	186	19	0	176	21	0
Drawing task <sup>b</sup>	6.9 <sup>c</sup>	1.3	4 <sup>d</sup>	9.1 <sup>c</sup>	1	0

<sup>a</sup>ANOVA (two groups · three visual conditions · three angles) indicating a main effect of visual condition  $F(2,28) = 23.8$ ,  $P < 0.00001$ , an interaction between visual condition and angle  $F(4,56) = 6.3$ ,  $P < 0.001$ , but no group effect.

<sup>b</sup>Scoring range from 0 to 10. The highest score represents a perfect correspondence between the actual map of the virtual corridor and the schematic representation of the subject.

<sup>c</sup>Mann–Whitney  $U$ -test,  $U = 4.5$ ,  $P < 0.01$ .

<sup>d</sup>These errors always occurred when drawing the 45° angle, which is the last angle of C3.

Nevertheless, the results did not demonstrate unequivocally that the sensory cue having the greatest amplitude was reproduced. This indicates that perception is based on a weighted average over the different available stimuli. Yet, no relationship between anxiety and post-effect of the conflict on the reproduction of the path was exhibited.

### Drawing task

HTA individuals exhibited a deficit in the drawing task when compared to LTA individuals. LTA subjects reproduced the essential features of the corridor: number, direction and order of angles. In contrast, five HTA subjects made a mistake in the direction of the last angle and the representation of angle amplitude was only approximate (Table 1).

### DISCUSSION

Previous studies have reported the existence of a non-vestibular strategy for maintaining balance in patients with SMD, agoraphobia and panic [4,5,15,16]. The results of a study on adaptation to a visuo-vestibular conflict in anxious subjects suggested that these subjects

could be more sensitive to conflicting sensory situations [12]. This hypothesis remained entangled with the possibility of a predominance of visual information for multisensory spatial orientation in anxious subjects. However, we found no evidence for a link between anxiety trait and dominance of visual information in the present sample. Indeed, these results suggest that visual dominance is not influenced by anxiety trait, although the procedure used (small number of subjects as well as no maintenance of postural balance involved in the task) may not have been sufficiently sensitive to detect a relationship between sensory integration parameters and anxiety. Nevertheless, it has to be noted that none of the HTA subjects in the present study had motor control impairment when they navigated in the corridor in conflict conditions. Furthermore, they did not show any specific post-effect of the conflict. However, they were less accurate in reproducing the direction of turns, particularly in conflict conditions. On the other hand, we observed a clear distinction between the memorized navigation task, which relies on egocentric cues (body-centered coordinates), and the map-drawing task, which requires a more global spatial representation.

There are several possible explanations for the poor performance observed in HTA group: (1) HTA sub-

jects have specific difficulties in activities requiring the intervention of non-egocentric reference frames; (2) the conflict requires an increased use of attentional resources in HTA subjects, suggesting a high sensitivity to sensory conflicts in HTA. These alternatives will next be discussed, as well as the hypothesis to which they could lead.

### **Anxiety and non-egocentric frame of reference**

There are different ways of representing spatial information (see for example [14]). One solution relies on the measurement of instantaneous relationships of one's self with respect to the features of the environment (egocentric representation). This type of representation must, therefore, be updated over self-motion. Alternatively, one can encode an environment on the basis of its invariant aspects, through its geometric shape for example (allocentric representation). This solution is independent of self-motion. Both solutions have different characteristics and advantages. While the first one is orientation specific, the second one is orientation free. The orientation free representation leads to better orientating behavior in space since it is not linked to a viewer-centered point of reference. The poor performance of HTA subjects in the map drawing task could, therefore, represent a deficit in this type of representation. Indeed, the results of a previous study exhibited a preference for the use of an egocentric strategy in high anxious subjects for orientation in space [13]. This strategy could be linked to the difficulty that our HTA subjects, as well as panic agoraphobic patients [7], had in creating a map-like spatial representation.

The hippocampus plays an important role in allocentric aspects of spatial memory. While the specific role of hippocampus cannot be inferred in the present study, several studies have pointed out a link between this structure and anxiety mediated by corticosteroids [9,10]. Indeed, the hippocampus provides negative feedback to the HPA axis. Following this line of reasoning, we suggest future studies on spatial cognition to take a closer look at these links by studying high trait anxiety under non-stressful conditions.

### **Anxiety, sensory conflicts and attentional load**

HTA subjects exhibited poorer performance than LTA subjects in terms of direction reproduction in sensory conflict conditions (see *Table 1*). This lowered perfor-

mance, as well as the deficits in map-drawing, may result from differences in the allocation of attentional resources between groups. HTA subjects may be more sensitive to the sensory conflict and would, therefore, devote more attentional resources to its resolution [12]. From this point of view, the poorer results of the HTA group would be a consequence of their higher sensitivity to the conflict on one hand, and higher attentional demands to adapt to this conflict on the other hand. Alternatively, HTA subjects may simply have a more generally reduced information-processing capacity, as suggested for the link between orientation deficits and dizziness [17]. In either case, a reduction in the remaining resources would in turn weaken the central processing of information required to memorize the path. Indeed, if conflict makes significant demands upon cortical multisensory processing, it is possible that insufficient resources would be available to store the information relevant to the trajectory.

These ideas lead to the hypothesis that the development of pathological anxiety could be concomitant with the loss of attentional resources caused by the need to continuously adjust the relative weighting of multisensory information. In the case of a complete loss of resources, anxious individuals would no longer be able to cope with the attentional load needed to overcome instability originating from their high sensitivity to the conflict, thus inducing more anxiety symptoms, distress and avoidance behavior.

### **CONCLUSION**

Our observations are in line with the hypothesis of a high-level sensory integration problem in anxiety, which would extend its effect to the perception of orientation in space. Visual and idiothetic cues (vestibular, proprioceptive and efferent motor commands) are the root of spatial processing. More than a dependence on a particular sensory modality, we propose that HTA subjects, like subjects with symptoms of panic and agoraphobia [7], have a strong dependence on a particular reference frame in which the sensory information are interpreted and in which the subject would remain anchored [13]. However, in the present experiment, the relationship between the integration of sensory information in conflict conditions and the demonstrated difficulty in constructing a coherent representation of space from memory must still be clarified. The present findings, if confirmed by studies on larger samples, have implications for research on subjects with



symptoms of panic and agoraphobia; if weighting of different sensory information is deficient in people with these symptoms it should be possible to observe its effects in spatial orientation tasks. These points will need to be considered when designing new experiments on space representation in anxious patients.

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