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Research report

The impact of subliminal haptic perception on the preference discrimination of roughness and compliance

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ABSTRACT

It is well known that unaware exposure to a visual stimulus increases the preferability of the associated object. In this study we examine whether the same phenomena occur for haptic stimuli. Using a touch-enabled virtual environment, we tested whether people that touch two virtual surfaces, which differ by imperceptible differences in roughness or compliance, tend to choose rougher or smoother, softer or stiffer surfaces, in accordance with their natural tendency. In forced choice preference tests, participants were first asked to choose between two surfaces that differ by roughness/stiffness. Stimuli strength was above the aware perception limit. Then, the same test was performed for differences in stimuli strength, which was below the limit of awareness. Finally, we carried out a recognition test: participants were asked to choose between the surfaces presented in the previous step, and point at the smoother or softer surface, respectively. For each stimulus, two groups of 26 subjects participated. Results show that in the unaware preference tests, participants selected the surface in accordance with the aware preference tests, with significant difference from chance (59.5%, and 60.2% for roughness and compliance as a stimulus, respectively). The recognition tests in both experiments were at chance level, suggesting that participants were unaware of the difference in stimuli. These results show that subliminal perception of roughness and compliance strength affects texture preferences. Research data suggest that the amygdala is central in regulating emotional processing of visual stimuli, even if it is presented subliminally. Thus, the results of this study raise the question whether the amygdala also modulates emotional haptic stimuli when they are subliminally perceived.

1. Introduction

People exposed to sensory stimuli, prefer certain stimuli better than others. Many studies have been done on the aesthetic preference of visual and auditory stimuli in art and music respectively [22,35]. Also, in everyday life we experience affective reactions towards visual, auditory, olfactory, and taste stimuli [12,15,21,25].

People also react affectively to haptic stimuli [2,33,39]. In particular, they show preferences towards surface properties of physical objects. In a study of texture preferences, Ekman et al. [9] found that in general, subjects' preference was directly proportional to surface smoothness. Chen et al. [7] found a linear correlation between affective response and surface softness.

Affective response to sensory stimuli happens even if stimuli are presented in degraded conditions, below the level of aware perception. This effect, coined in this study as subliminal perception, occurs whenever stimuli, presented below the aware threshold, are found to influence thoughts, feelings, or actions [23]. Measuring the dependent variable, i.e. influences, is relatively not complicated. Difficulty arises in assessing awareness of a stimulus below the subject's threshold [24]. To overcome this problem Kunst-Wilson and Zajonc [17], introduced a novel method to determine unaware perception in response to subliminal stimuli. Zajonc [41] demonstrated that participants that were exposed to an object, tend to find it more attractive, relative to other objects. Later on, it was shown by Kunst-Wilson and Zajonc [17] that the same effect happens when the stimulus is primed under unaware conditions. In their experiment, participants were briefly exposed to a visual stimulus, then they were asked to compare between two stimuli under normal conditions. One stimulus was new, and the other was the previously shown-stimulus, on a subliminal level. Two forced choice tests were conducted. In the first, subjects indicated their preferred stimulus (preference test). In the second test, participants were asked to indicate to which stimulus they had been exposed before (recognition test). While recognition performance was at chance level, participants preferred the subliminally exposed stimuli 60% of the choices. Recognition at chance level provides clear evidence that an unaware stimulus influenced preferences

Subliminal perception was widely investigated in the context of visual stimuli [29,32]. There is some evidence of subliminal percep-

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tion in the auditory and tactile systems too [13,19,38]. In a previous study we brought evidence that subliminal perception influenced manual actions [14]. When subjects glided a stylus-like handle on a virtual surface with an imperceptible change in roughness, participants changed the magnitude of the force applied in the normal direction (action).

Several studies have shown that the amygdala is activated, not only in response to negative sensory stimuli, but also in response to pleasant stimuli [5,11,18,34,44]. In particular, activation of the amygdala was observed when subjects were exposed to pleasant tactile stimuli [30,31].

The amygdala is activated even when visual stimuli are presented at subliminal level [26,27,32,40]. The stimuli in those studies had aversive content.

There is a debate between two points of view on the brain mechanism, which leads to the activation of the amygdala when subjects are exposed to affective sensory stimuli, including those that mediated the growth of positive affect or preferences [17]. The first point of view claims that affect and cognition are independent entities [20,42,43]. This implies that subjects recognize emotional signals via a subcortical route [1]. The second approach points out that affect and cognition are highly interdependent [37], meaning that sensory cortical processing is necessary for the amygdala affective activation. To verify their claims, researchers from both streams performed experiments in animals and humans, when stimuli were subliminally presented. Summaries can be found in Zald [44] for the affect-cognition independent view and, in Storbeck and Clore [37] for the affect-cognition interdependent view. The main discrepancy between the presented results, is that the second approach suggests that neural activation of the visual cortex, even if it is unaware, is necessary for the activation of the amygdala [28,36].

The aim of this research was to investigate the impact of unaware haptic perception on the preference discrimination of surfaces with subtle differences in roughness and compliance. Using a hapto-visual virtual reality device in which participants interact with virtual surfaces through a pen-like stylus, we run two experiments. The stimuli were imperceptible changes of surface roughness in the first experiment, and imperceptible changes in surface stiffness in the second. We used a method similar to that applied by Kunst-Wilson and Zajonc [17]. Instead of priming stimuli, we compared preferences in forced choice experiments, under degraded conditions in accordance with participants' natural preferences. Then we run discrimination tests to check if the differences of the surfaces properties were perceived unawarely. To asses personal preferences we ran preference tests with stimuli differences above the aware perception limit.

In this study we use haptic stimuli consisting of surface roughness and compliance in a comparison forced choice paradigm in order to answer the following research question: does unaware perception of surfaces by indirect touch have an impact on subjects' preferences in accordance with their natural inclinations?

2. Materials and methods

2.1. Subjects

Two experiments were carried out. In the first, surface roughness was the stimulus (Experiment 1). In the second, surface stiffness was the stimulus (Experiment 2). In Experiment 1 participated 26 subjects, 13 females and 13 males (mean age 29.6). In Experiment 2, 26 subjects (different individuals than in Experiment 2) took part in the experiment, 13 females and 13 males (mean age 29.2). All procedures were performed in accordance with the ethical standards established in the 1964 Declaration of Helsinki.

2.2. Experimental setup

We used a 3D hapto-visual virtual reality with a haptic interface (The DESKTOP PHAToM from SenseAble Technologies Inc.). We developed 3D VR objects that can be seen, touched, and manipulated, with arbitrary programmable physical properties (see Fig. 1).

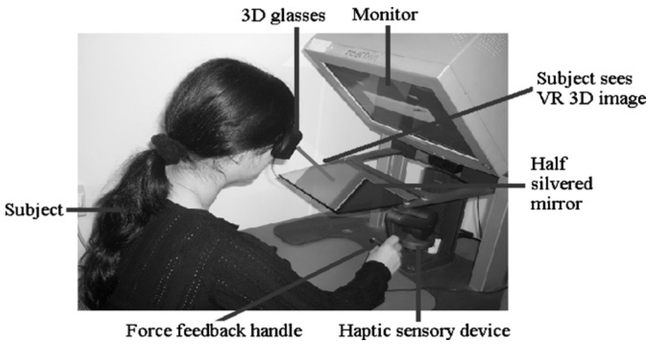

Fig. 1. Experimental array. The participant interacts with a virtual 3D object using a haptic interface. The visual and physical properties of the virtual objects are programmable, and the participant's responses are saved.

For both experiments the visual setup was identical. It consisted of two identical shaped surfaces (see Fig. 2). In a selection test, by pressing one of the triangles, the surface towards it was pointed to, was recorded in the output file as up or down. Five different geometrical shapes were used, but they were always identical in each trial.

2.3. Stimuli

2.3.1. Experiment 1

The parameter we used to vary the surface degree of roughness was the dimensionless friction coefficient (μ) defined as the ratio between the friction force between the surfaces in contact, and their mutual normal force. In all stages, randomly, one of the surfaces was kept at a constant value of $\mu = 0.1$. A value of μ was assigned to the second surface, depending on the task.

2.3.2. Experiment 2

For changes in surface compliance we used the stiffness coefficient (k). The stiffness coefficient is a measure of the resistance of the elastic body to deformation. It is defined as the force applied to the body, divided by the displacement caused by the force. In our study the units of k are Newton/millimeter. As in Experiment 1, one of the surfaces was kept at a constant value of $k = 0.1$ N/mm.

2.4. Task

2.4.1. Experiment 1

2.4.1.1. Aware preference test phase. The values we used for μ were based on the results of our previous study on subjects' limit of aware perception of changes in

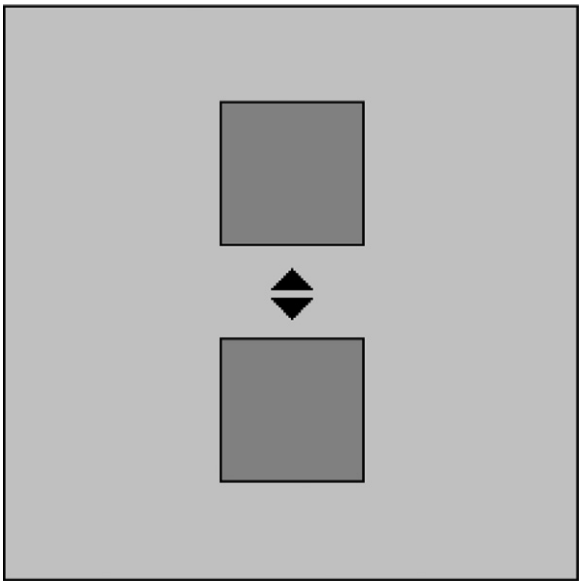

Fig. 2. Schematic representation of the experimental setup for both experiments. By pressing one of the triangles, the surface towards it is pointed to, is recorded as up or down.