Call for applications for a thesis funded by the ONERA ENAC ISAE-SUPAERO Federation.

Study of tactile illusions using Gestalt theories to design robust vibro-tactile feedbacks for the cockpit

Research teams: Interactive Computing Team at ENAC / Cognitive Engineering and Applied Neuroscience Team at ONERA Salon de Provence
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Duration: 36 months, October 2024 - September 2027
Location : ENAC and ONERA Salon de Provence

Keywords

Vibro-tactile feedback, tactile illusions, tactile perception, cognitive science, Gestalt, Human Machine Interaction (HMI), cockpit

Abstract

Tactile perception is crucial to the human sensory experience and plays an essential role in our interaction with the environment. In the context of piloting, vibrotactile feedback is used to provide information in addition to the visual and auditory channels. However, the processing of this vibrotactile feedback can sometimes lead to perceptual distortion (tactile illusions).

The aim of this thesis project is twofold. The first contribution is to understand, based on Gestalt principles, how the human brain organises tactile stimuli to form a percept. The second contribution will be to use this knowledge designing vibrotactile feedback techniques that are more accurate and more resilient to perceptual distortions, particularly for the management of critical systems.

Applying this research to the aeronautical industry will help to improve the safety and management efficiency of critical systems by enhancing the design of tactile interfaces for pilots.

Context and objectives

This thesis is at the crossroads of research in human-machine interaction and cognitive science.

Tactile perception, which involves the sense of touch, is an essential component of the human sensory experience. It plays a fundamental role in the way we interact with our environment [4]. For control management, and in particular for critical situations requiring immediate action [2,6], vibrotactile feedback can provide information about the aircraft's own movement (e.g. the relative position of the aircraft with respect to the surrounding environment, attitudes in the terrestrial reference frame, etc.) alongside that already transmitted via visual and auditory channels. However, the processing of vibrotactile feedback can give rise to a distorted perception of the movement itself [7]. This cognitive permeability of tactile perception has been studied using tactile illusions [1,3,5]. In this context, designing vibrotactile feedback for critical systems management is challenging because the lack of the illusions characterisation, recommendations and studies in ecological flight situations).

To support practitioners in designing vibrotactile feedback that is resillient to illusions, this thesis project aims to explore the mechanisms underlying the tactile perception of such illusions. In particular, we will examine the way in which human forms a percept from the tactile stimuli. For example, we know that a rapid sequence of taps on the wrist and then near the elbow generates the perception of a stimulus moving up the forearm from the wrist to the elbow, even though no stimulus is applied between the two stimulated areas (i.e., cutenaous rabit illusion). By attributing a spatio-temporal structure to a sequence of percepts that initially has none, such an illusion demonstrates the human nervous system's ability to predict and anticipate the sensory consequences of stimuli. This cognitive mechanism for structuring visual and auditory information was extensively studied in the first half of the 20th century as part of Gestalt theory.

This thesis will investigate these mechanisms for the tactile modality and the results will be applied on designing vibro-tactile stimuli that are 1/ more faithful to the information that needs to be transmitted and 2/ more robust to the ecological context. In particular, we will question the existence of principles of the Gestalt theories for the tactile modality [1,3,5], and explore how such principles can guide the design of vibrotactile feedback in tools for critical system HMIs.

This research will be carried out in the aeronautical piloting domain. Firstly, we will conduct laboratory experiments to assess how Gestalt principles apply to tactile perception and how they can influence the occurrence of illusions. Secondly, we will study the resilience of this type of illusion in an ecological piloting situation (static and dynamic flight simulator) and the design principles that can be used to avoid or trigger them. The results will enable us to understand how Gestalt theory can be applied to the perception of vibro-tactile stimuli and how it can be useful for balancing the phenomena of harmful perceptual distortion in aircraft piloting situations. A better understanding of human sensory perception is an essential step in the design of tactile interfaces.

Outline

1st year:

- Review of the scientific literature on: the mechanisms underlying tactile perception; gestalt theories (auditory vision, tactile); vibrotactile feedback design principles; tactile illusions; vibrotactile feedback for critical systems management.
- State-of-the art article writing
- Pilot interviews/observations to identify scenarios for using vibrotactile feedback
- Definition of experimental protocol for evaluating tactile illusions using gestalt theories

Year 2:

- Experimentation, data analysis and article writing
- Characterisation of the occurrence of illusions and definition of an experimental protocol for studying the occurrence of illusions in an ecological driving situation (using the scenarios identified above).
- Experimentation in an ecological situation and design of vibrotactile feedback to reduce the risk of illusion.

Year 3:

- Evaluation and re-editing of articles on the design principle for illusion-resistant vibrotactile feedback.
- Drafting of thesis manuscript

PhD Candidate's Profile

- Master 2 research or engineering degree in human-computer interaction, computer science, cognitive science, robotics, neuroscience;
- Strong interest in human-computer interaction, computer science and cognitive science;
- Skills in programming (Python, Qt, C++) and in electronics and mechatronics;
- Self-motivated and rigorous.

Application procedure

Applications should be sent to Sylvain Pauchet (sylvain.pauchet@enac.fr) and Jean-Christophe Sarrazin (jean-christophe.sarrazin@onera.fr).

Applications should include a CV, a covering letter, copies of grades and rankings from the M1 and M2 exams (if available). The M2 report (if available) and any other documents you consider useful. Samples of published research by the candidate will be a plus.

References

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