Gestural and Postural Reactions to Stressful Event: Design of a Haptic Stressful Stimulus

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***Abstract*—Previous studies about kinesthetic expressions of emotions are mainly based on acted expressions of affective states, which might be quite different from spontaneous expressions. In a previous study, we proposed a task to collect haptic expressions of a spontaneous stress. In this paper, we explore the effectiveness of this task to induce a spontaneous stress in two ways : a subjective feedback, and a more objective approach-avoidance behavior.**

***Keywords*—Stress; Postural Reaction; Haptic Perception**

I. Introduction

Emotions play a key role in human communication [1]. The expression and perception of emotions, exploits and combines various non-verbal modalities (visual, auditory, etc.). Research up to now has mainly focused on the study of specific modalities as facial expressions [2], [3].

Recent work has shown that the haptic modality is efficient at conveying some emotions by means of specific touch patterns [4]. With the development of human–machine interfaces and communication technologies, haptic devices for remote and mediated communications have been proposed [5]. This research raises two issues. The first issue concerns the limits of existing haptic devices in reproducing realistic tactile expressions of feelings [6]. The second issue concerns the identification of haptic models, i.e., tactile, kinesthetic patterns and physical features to effectively express different emotions [7]. While research in the field of haptic stimulation and rendering technologies is promising for affective and social communication [8], [9], the identification of efficient haptic models is still a big issue.

The identification of affective models is often based on the analysis of a corpus of affective expressions (facial, gestural, etc.). Such a corpus contains expressions of acted emotions where the subjects are explicitly asked to express an emotion [3]. However, the analysis of different corpora of emotional expressions (for instance, in speech [10]) has highlighted significant differences between expressions issuing from acted emotions and those issuing from spontaneous emotions. Wilting has even said, about their work on the speech modality: "Acted emotional speech is not felt, and is perceived more strongly than real emotional speech. This sheds doubt on the use of actors for emotion research, especially if the goal is to study real emotions." [11]. This explains why recent studies tend to collect more spontaneous affective expressions. Surprisingly, current research in affective haptics still focuses mainly on the expressions of acted emotions.

This paper presents a stress measurement during a task designed to collect haptic expressions of a spontaneous stress. Stress is a pattern of negative physiological states and psychological responses occurring in situations where individuals perceive threats to their well-being, which they may be unable to meet [12]. The study and the identification of its related emotional states is important for several reasons. First, stress is recurrent in everyday life, for example, during exams or job interviews. Thus, it plays a key role in human–human communications [13], [14]. Second, stress is linked to some health problems, such as depression and cardiovascular diseases [15]. Therefore, it is important to detect this emotional state in order to quickly diagnose these diseases. Finally, stress might be a cue for detecting emotions such as irritation or anxiety, which are hard to detect with facial expressions or prosody [16].

Stress responses can be measured subjectively and objectively. Subjective measures of stress cover a variety of questionnaires ([17]) developed to asses the psychological factors that are associated with stress responses. Objective measures of stress include a variety of studies developed to analyze the physiological responses to stress situations [18]. These responses can include several physiological signals [19] (increased salivary cortisol levels, increased blood preasure, increased heart rate, increased electrodermal activity, etc.). Although psychological measures have shown to provide several indicators of stress, there is a considerable variation in level and type of hormones released by different people and in response to different stressors.

In the current study, we focus on approach and avoidance behaviors to measure the efficiency of the stress induction. Psychological studies [20], [21], [22] have demonstrated that spontaneous stress of people is closely linked with their approach and avoidance behaviors. Roelofs et al. [21] investigated whether increased cortisol stress-responsiveness is linked to increased social avoidance behavior in patients with social anxiety disorder (SAD). The results showed that social stress elicited increased avoidance tendencies towards social threat stimuli in SAD. Heuer et al. [22] employed an Approach–Avoidance Task in order to investigate avoidance reactions to stimuli of potential social threat. The results showed that socially anxious individuals (HSAs) showed stronger avoidance tendencies than non-anxious controls (NACs) for smiling as well as angry faces. Therefore, the detection of these behaviors can provide an objective cue regarding their stress response.

The rest of this paper is structured as follows. The next section introduces the proposed task involving haptic inter-

action to induce a spontaneous stress. Section presents the measurement of stress in this task computed from participants. Section presents the results. Finally, section V concludes the paper.

II. Scenario And Stimulus For Stress Induction

There are three common methods to induce an affective state: media supports, social interactions and video games. Those methods are discussed in one of our previous work highlighting several guidelines to design a task involving haptic interaction inducing spontaneous affects [23]. Considering these guidelines, we adopt in the current study a scenario based on an interactive game. Games motivate users and lead them to forget the experimental setting, while providing a controlled environment [24]. This approach enables the induction of a variety of emotions (e.g., joy when winning, frustration when losing).

Our scenario is based on a racing arcade game displayed on a standard desktop computer with a 22 inch screen. The rule of the game is simple: a car is running on a three-lane road. The car's movement is limited to one dimension (left–right) and controlled with the Geomagic Touch device. On the road, several obstacles appear and must be avoided (see Fig. 1a). These obstacles lead the participants to move the car. Forcing the movement is important since the final objective of the study consists in analyzing the participants' gestures. A game score (corresponding to a life-bar of the car) decreases when the car collides with obstacles. This bar intends to increase their stress during a stressful stimulus.

This stimulus was a sudden reduction of the visibility of the road by cutting the upper half of the screen without prior notice after 40 s (see Fig. 1b). Thus, the obstacles would appear at the last moment, then it would be more difficult to avoid them. After 23 s, the visibility is restored. The reduction of visibility does not change the task (i.e., driving and avoiding obstacles). Thus, the variations of the participants' behavior are expected to be directly linked to the stressful stimulus.

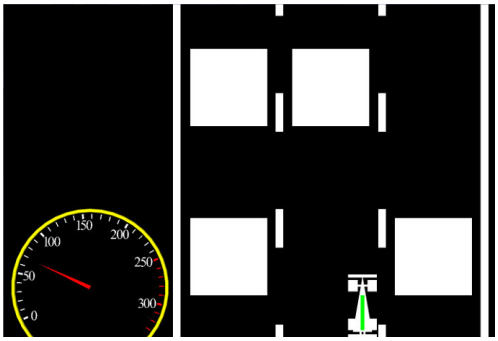
III. Experiment

Based on our car-driving game, we designed an experiment to elicit stress and to collect the corresponding spontaneous haptic expressions.

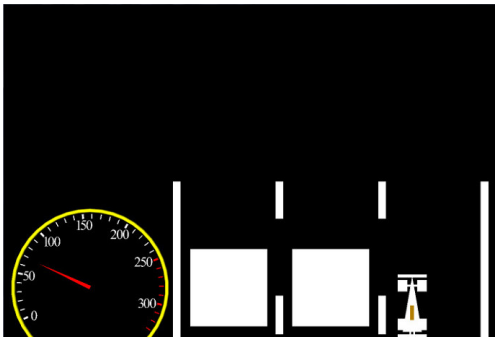
A. Hypothesis

This experiment investigates whether the stressful stimulus does induce the stress to participants. We defined our hypothesis as follows:

- H1 The reduction of visibility during the task induces stress. More precisely:
  - H1-a Participants report feeling stress under *T2*.
  - H1-b Participants show an avoidance behavior under *T2*.



(a) Without the stressful stimulus



(b) During the stressful stimulus (reduction of visibility)

Fig. 1: The "car driving" game task. Participants control the left–right position of the car with the haptic device. While the road scrolls, participants have to avoid obstacles (blank squares).

B. Experimental Setup

The experiment took place in an anechoic acoustic room to avoid any external visual or audio distraction. The participants were left alone in the room during the experiment.

The car driving game task was displayed on a 22 inch screen. The screen and a Geomagic Touch device were set on a desk (see Figure 2). A Logitech HD webcam c525 placed on the top of the screen recorded the participant's face.

C. Method

1) Participants: Sixteen right-handed males, average age 27 (SD = 3.6), ages 21 through 33, participated in this experiment.

2) Measures:

a) Subjective report of stress: To investigate stress related feelings, two types measures were used: subjective and objective measures.

For the subjective evaluation of stress, we asked participants a serie of three questions after completing the task. Participants answered on a 5-point Likert scale (from 1 to 5):

- M_S1 "I understood the task." This allows verifying that the task was simple to understand. This ensure the collected behaviors are not related to a misunderstanding.
- M_S2 "I was disturbed by an unexpected event." This intend to evaluate if participants expected an event.

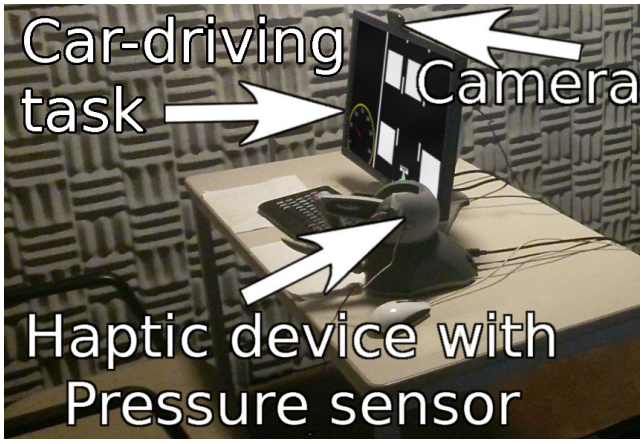


Fig. 2: Experimental setup to induce stress and collect corresponding haptic expressions. Participants played the car driving game using the Geomagic Touch device. During the game, the computer recorded their face using an HD camera.

- M_S3 "I thought I was controlling the situation (before this event)."
- M_S4 "I thought I was controlling the situation (after this event)."

The two last questions are inspired by the Perceived Stress Scale [17].

Following the Differential Emotional Scale procedure [25], participants reported their own stress level before and after the stimulus (respectively M_S5 and M_S6) using a 5-point Likert scale (from 1 to 5) by considered period of time. Twelve other emotions were also considered. This intended to disguise the measurement of stress.

b) Approach-avoidance behavior: For the objective evaluation of stress, we computed the approach-avoidance behavior of participants. To extract this measure, the recorded videos of the participants' faces were processed as follows. We used a software that allows detecting forward and backward movements of the participants based on the inter-ocular distance [26]. For each frame of the video sequence, the face and eyes of the participant are detected using the AdaBoost algorithm and Haar-like features [27]. Then, false eye detections are avoided using several heuristics based on the geometrical properties of the eyes and the face in order to ensure that the participant is actually facing the screen. Finally, the inter-ocular distance for each frame is obtained by computing the distance between the centers of the eyes (Figure 3). This distance is measured in pixel units. We considered the evolution of the inter-ocular distance in a small interval of time that begins three seconds before the stress induction and ends four seconds after the stress induction. The duration of the stress induction was 23 seconds. The resulting data (inter-ocular distance for each video frame) of all participants was then segmented according to the frames that belong to the entire time interval (30 seconds). The sampling rate of the time interval was chosen to be 0.5 seconds. These numerical values were selected after informal testing of the data. They are also consistent with experiments about reaction times following an emotional stimulus [28]. In order to compute the approach and avoidance behaviors for all participants, we used the following procedure:

1) The data segments obtained for all participants were transformed into a normal standard distribution (z-score values). Following this normalization, the approach–avoidance behaviors of all participants became comparable.
2) For each data segment, a baseline for the inter-ocular distance was calculated by averaging its measures during the interval before the stress induction (three seconds). This baseline served as a basis for comparison between the location of the participant before the stress induction and the location of the participant during and after the stress induction.
3) The normalized data of the interval during the stress induction (23 seconds) and after the stress induction (four seconds) was subtracted from the baseline in order to obtain an estimate of the corresponding approach–avoidance behavior. A positive value suggests an approaching behavior. A negative value suggests an avoidance behavior.

c) Haptic behavior: This experiment aims to study the influence of stress on haptic behavior. Then, the data from the haptic device and the pressure sensor were collected during the experiment. This section briefly describes the collected measures.

These measures were extracted from different periods of time: before the stressful stimulus, during the stimulus, and after the stimulus. They concern :

- Mean speed. This measure corresponds to the mean speed of the movements of participants.
- Jerkiness. This measure corresponds to the variations of mean speed. It describes if the movements of the participants were smooth or jerky.
- Applied pressure. This measure correspond to the intensity of the pressure applied on the button of the haptic device over time.

3) Experimental Procedure: The participants sat down in front of the computer screen (see Fig. 2). They signed a consent form for the video recording. The experimenter presented the game to the participants (the rules, the haptic interaction, obstacle management, etc.). Then, the participants received some training for thirty seconds, during which the game task was explained. The real objective of the experiment (studying haptic expressions of stress) was hidden from the participants. No stressful stimulus was presented during the training.

The experimenter asked them if they understood the task and if they had any questions. Before the experimenter left the room, he explained to the participants that the task would be exactly the same as during the training, but with a limited duration of one and one-half minutes. Then, the experiment and the game began. At the 40th second, for 23 seconds thereafter, the upper half of the screen was masked (see Figs. 1(a) and 1(b)). These durations were selected after preliminary tests.

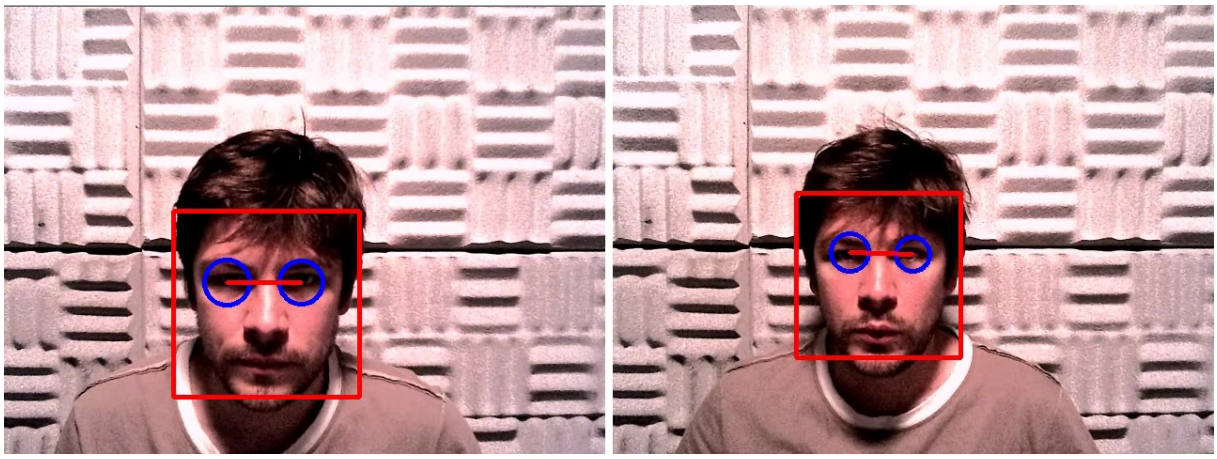


Fig. 3: Display of the inter-ocular distance (red line) computed on the recorded videos of participants. The right image shows an avoidance behavior relative to the position of the participant in the left image.

At the end of the experiment, the experimenter returned to the room and asked each participant to complete a short questionnaire, corresponding to measures M_S1 to M_S6.

IV. Results And Analysis

A. Haptic Behavior During The Task

The haptic behavior of participants during this task was investigated in our previous work [7]. This section resumes the main results.

The haptic behavior of participants changed during the presented stressful stimulus. Participants increased the mean speed and jerkiness of their gestures during the stressful stimulus. They also applied more pressure on the haptic device. However, after the presentation of the stimulus, the applied pressure went similar to the one recorded before the stimulus. The mean speed and jerkiness of their gestures remains significantly higher after the stimulus compared to the period before the presentation of the stimulus.

B. Subjective Perception Of Stress

As all participants reported they fully understood the task ($M_S1 = 5.00$, SD $= 0.00$), it is unlikely that a change of behavior resulted from a misunderstanding of the task. The task was also simple, and required continual interaction, designed to maintain the participant's attention.

They reported that they quite expected an event ($M_S2 = 3.31$, SD $= 1.30$). participants reported they thought they were losing control of the situation after the presentation of the stimulus, compared to the beginning of the experiment ($M_S3 = 4.50$ VS $M_S4 = 3.75$, p-value $= 0.0213$, $W = 78$). This is a clear indicator of stress [17], [12].

Concerning the subjective report of stress, participants reported they felt more stress after the stimulus than before ($M_S5 = 1.625$ VS $M_S6 = 3.125$, p-value $\ll 0.01$, $V = 0$) These results support **H1-a**.

C. Approach-Avoidance Behavior

Figure 4 shows the average result of the approach–avoidance behavior measures computed from all participants during the considered time interval (27 seconds after the stress induction started). The results showed that the participants reacted with an avoidance behavior (negative values) during stress induction: this avoidance behavior began to be shown approximately three seconds after the presentation of the stress stimulus (second 0). The results also showed that the participants reacted with an approach behavior when the stress induction finished (second 23). These results support **H1-b**.

According to the approach–avoidance behavior measure, participants perceived the stress induction (*T2*) as a negative stimulus and consequently they reacted with an avoidance behavior (Figure 4). It is important to note that the avoidance behavior (negative values) persisted for almost all the entire interval of stress induction (20 seconds), this could indicate that this avoidance behavior is closely linked with spontaneous stress of participants as suggested by psychological studies in approach–avoidance behavior and stress [21], [22]. The results also suggest that the participants felt alleviated when the stress induction was over (*T3*), and consequently they reacted with an approach behavior. However, it is possible that approach-avoidance behaviors were also caused by other factors (e.g. changes of posture) in the time outside the interval of stress induction (before or after stress induction).

V. Conclusion And Perspectives

In this paper, we proposed a relevant scenario based on an interactive game to elicit spontaneous expressions of stress in order to collect the corresponding haptic expressions. Stress of participants was measured using subjective and objective measures. In order to have a clear indicator of stress, we have analyzed the approach and avoidance behaviours of participants. These preliminary results suggest that participants perceived the stress induction as a negative stimulus reacting with an avoidance behavior. However the number of participants was still limited to consider an avoidance behavior as a clear indicator of stress. More participants will be added to

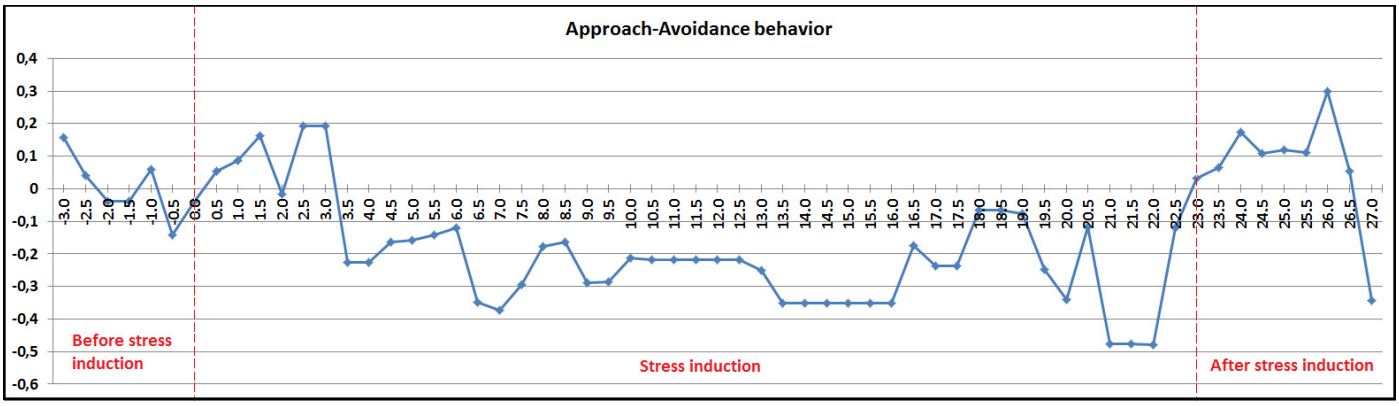


Fig. 4: Inter-ocular distance during the time interval of stress induction (23 seconds) and after the stress induction (23–27 seconds). Data above 0 describes an approach behavior while data below 0 describes an avoidance behavior.

the presented experiment in order to study the relation between approach-avoidance behavior and spontaneous stress.

Future work will investigate the generation of haptic stimuli based on the approach-avoidance behavior observed. We will also investigate the haptic expressions and perception of other emotions, such as joy or anger, usually found in natural human–human communication. We will also consider the integration of the haptic expressions with other modalities. Further studies will also investigate if the haptic behavior change during the stress induction.

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