

Haptic Expressions of Stress During an Interactive Game

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Abstract. The study of the potential of haptic channel to convey emotions is very promising for human-machine interaction and mediated communication. However, main researches investigated acted emotions that are not representative of natural and spontaneous behaviors. This paper addresses the issue of expression of spontaneous emotions. In the context of a game application that involves haptic interaction, a suitable scenario and context were designed to elicit a spontaneous stressed affective state. The haptic behavior of participants was subsequently analyzed in order to highlight the changes during and after the elicitation of this affective state.

Keywords: Emotion, Spontaneous Expression, Haptics, Experimental Study

1 Introduction

The study of emotions is a recent challenge in the field of haptics. In human-machine interaction and mediated communication, haptics might provide new sensory channels that might effectively support different dimensions of emotions through the physical contact (e.g. pleasure, dominance and arousal).

Several researchers investigated the potential of the haptic channels to convey emotions. Hertenstein et al. [7] observed that humans effectively communicate different categories of emotions with different interpersonal touch patterns. They identified specific patterns and physical features used by participants to communicate specific emotions. Other studies highlighted the role of the tactile channel to support social interactions and to form and maintain social bonds [8]. In the field of mediated communication, several tactile devices were successfully experimented for supporting affective interaction between users and virtual humans or social robots [12]. However, these works focus on the study and analysis of acted expressions of emotions: participants are asked to explicitly express an emotion that is specified by a label (e.g. Joy). The resulting haptic acted expressions are not representative of natural and spontaneous behaviors that may occur in daily life [11].

The study of spontaneous expressions of emotions is quite relevant because it can be used for the identification of emotional states (Stress, Joy, etc.) from the

analysis of the haptic behavior during interactions tasks (e.g., games). Moreover, the analysis of the spontaneous expressions allows the identification of relevant haptic features and patterns to include in mediated communication in order to effectively communicate some complex emotions such as anxiety and elation.

This paper focuses on Stress which 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 [9]. In the study described in this paper, the stress is elicited during a game that involves a haptic interaction. The collected haptic expressions are then collected and analyzed in order to highlight the changes of haptic behaviors during and after the elicitation of the Stress.

The rest of the paper is structured as follows: Section 2 presents the constraints of elicitation of emotions and the adopted game and scenario. Sections 3 and 4 present the experimental study and the analysis of the haptic expressions. Finally, Section 5 presents a discussion and concludes the paper.

2 Collecting haptic expressions of spontaneous emotions

The experimental study of spontaneous emotions raises multiple questions. Eliciting natural behaviors in laboratory conditions is a difficult task since participants are aware of the experimental context [3]. This kind of study requires the identification of a suitable elicitation, sufficiently convincing and completely transparent for participants. The use of the haptic channel introduces additional technological and psychological constraints: participants have to physically interact with the system during the phase of emotion elicitation (since we want to analyze haptic expressions of elicited emotions). In a previous paper, we systematically considered methodological constraints related to haptic and emotions [5]. These constraints can be summarized as follows:

- **C1 Intimacy:** Touch raises the problem of violation of intimacy for some cultures and for some individuals. This makes spontaneous affective haptic behaviors harder to observe in comparison with other modalities such as facial and postural expressions.
- **C2 Intrusiveness:** Current technologies for measuring haptic behaviors, such as the exerted force, require a physical contact between the user and the mechanical sensors. This constraint reduces the freedom of movements of participants and thus might lead to less natural expressions of emotions.
- **C3 Rendering:** Once collected, the affective haptic expressions must be rendered faithfully with a haptic device. The next objective of this study is to determine if the emotion that was elicited can be perceived by other participants to whom the collected haptic expressions are presented.

Following the study of a series of scenarios in which these constraints have been taken into account, we selected an interactive game task. Games motivate participants and can get them engaged in a way that is conducive for the expression of affective states [6]. Moreover, this engagement can lead participants

to partly forget about the experimental setting and thus induce spontaneous behaviors.

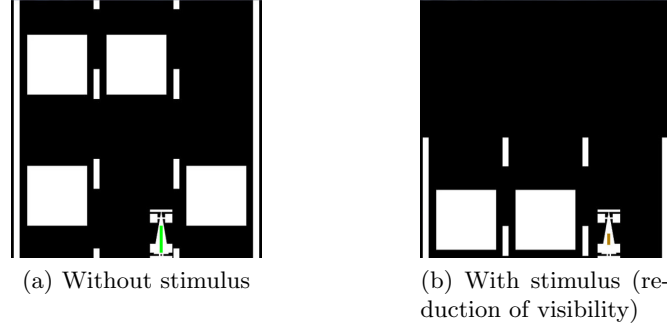


Fig. 1: The "car on a three-lane road" game task displayed on the experimental platform. Participants control the left-right position of the car with the haptic device. While the road scrolls up and down, participants have to avoid obstacles (represented by blank squares).

The rule of the game is simple and is inspired by a standard arcade game: a car running on a three-lane road. Participants can only control the left-right position of the car. On the road, several obstacles appear and must be avoided (see Fig. 1(a)). The gaming score (displayed in real time by a life-bar on the car) decreases when the car collides with obstacles.

In order to elicit stress, after a predefined period of time (40 s), the road visibility is suddenly reduced by cutting the upper half of the screen without prior notice (see Fig. 1(b)). Thus, the obstacles appear at the last moment and it becomes much more difficult for the participant to avoid them. After some time (23 s), the initial visibility is restored. It is important to point out that the reduction of visibility does not change the task per se (e.g. driving and avoid obstacle). Thus, variations in participants' behaviors are expected to be directly linked to the stressful stimulus.

3 Experimental Study

We conducted an experiment in order to study the impact of the stressful stimulus on the haptic behaviors displayed by participants. Three periods of the game were thus considered: before (**T1**), during (**T2**) and after (**T3**) the stressful stimulus. For each period of time, we measured and analyzed the haptic behaviors of participants in terms of applied force and movement features.

3.1 Hypotheses

The following hypotheses were considered:

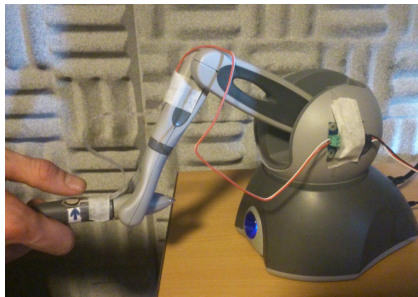
- **H1** The reduction of visibility during the task elicits Stress. This hypothesis is tested using a self-report questionnaire, without explicitly mentioning stress in the questionnaire.
- **H2** The features of the haptic behavior present differences between **T1** and **T2**. This hypothesis aims to point out a change in the haptic behavior as a consequence of the stressful event.
- **H3** The features of the haptic behavior present differences between **T1** and **T3**. If **H2** is verified for a given feature of the haptic behavior, **H3** assumes that the stressful event will still have an impact even when this stressful stimulus has stopped.

H2 and **H3** were investigated for each component of the haptic behavior (see measures below).

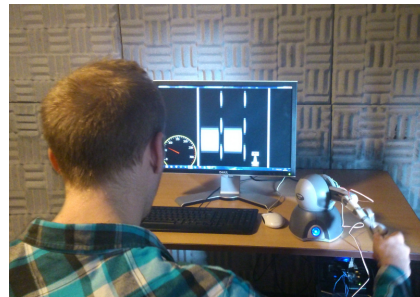
3.2 Experimental Platform

Considering the constraints of intrusiveness (**C2**) and rendering (**C3**) presented above, we decided to use a Geomagic Touch haptic arm. A FlexiForce force sensor, of type of SEN-08713 (<http://www.flexiforce.com/>), was added on the device's button to measure the exerted force during the game (see Fig. 2(a)). This interaction configuration is very close to that of usual games that use joysticks. Thus, the collection of haptic expressions is expected to be transparent to participants. Moreover, the haptic device enables a faithful rendering of collected haptic expressions for subsequent perceptive studies (see **C3**).

Based on this control and interaction device, a platform of racing arcade game was developed with a standard desktop computer and a 22 inches screen. The game provides a 2D display presenting a car running on a three-lane road. A series of obstacles appear during the game and a vibration feedback is generated whenever the car collides obstacles. The position of the car is controlled with the haptic device according to the horizontal axis from left to right. Finally, participants should not be disturbed by outside noises or lighting changes. This could influence their emotional state or disrupt them during the experiment. For this



(a) Geomagic Touch with force sensor



(b) Experimental setup

Fig. 2: The force sensor configuration (left) and the experimental setup (right).

reason, the experiment took place in an acoustic anechoic chamber. Participants were alone in the room during the task. The presence of an experimenter in the room during the task might inhibit their behavior (see **C1**) [3].

3.3 Method

Participants: Sixteen right-handed males, twenty-seven average age (SD = 3.6), ages twenty-one through thirty-three, participated in this experiment.

Measures: We computed several force and movement measures ($M_{O}i$ below) that were used in previous studies and observed to be relevant for discriminating emotional haptic behaviors [1, 2]). The force measure was computed from the force sensor data. The movement measures were computed from the sequence of 3D-points $[(x, y, z)_1, (x, y, z)_2, \dots, (x, y, z)_n]$ corresponding to the recorded movement. The sampling rate was 1 ms.

- **M_{O1} Force:** Exerted force on the device’s button (FlexiForce force sensor).
- **M_{O2} Mean Speed:** Average speed of the end-effector.
- **M_{O3} Fluidity:** Expresses the degree of smoothness of the movement. It was calculated with the following equation: $\sum_{t=0}^{n-1} |a(t+1) - a(t)| / n$, with $a(t)$ the acceleration at time t .
- **M_{O4} :** Expresses the prevalence of the major axis on the movement (based on SVD).
- **M_{O5} Weight of Second Major Axis:** Expresses the prevalence of the second major axis on the movement (based on SVD).

These measures were computed only when the participant pressed the device button to be sure that he was driving the car. In order to provide the same level of difficulty and the same task features for all participants, each participant encountered exactly the same sequence of obstacles during the game. This sequence was reset at the beginning of **T1**, **T2** and **T3** in order to enable comparison of the three periods (i.e., before, during and after the stimulus).

To investigate stress related feelings, we asked participants four questions at the end of the experiment in the following order. Those questions were inspired by the Perceived Stress Scale [4]. 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.
- **M_S2** "I was disturbed by an unexpected event". This allows verifying that participants did not expect the reduction of visibility.
- **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 last two questions allow verifying whether participants felt stress during the task.

Experimental Procedure: Participants were asked to take place in front of the computer (see Fig. 2(b)). The experimenter explained that they were going to participate in an experiment that deals with the perception and manipulation of virtual objects using a haptic device. The real objective of the experiment (studying haptic expressions of stress) was hidden to participants. The participants used the haptic device to explore the available space. They received precise instructions on the way to hold it (as if they were grabbing a wrist, the thumb on the button of the device). Then, the participants had a training of thirty seconds during which the gaming task was explained. The experimenter asked them if they understood the task and if they had any questions. Before leaving the room to let the participants alone, the experimenter explained them that the task would be exactly the same as during the training, but with a limited duration of one minute and a half. At the 40th second of the task and during 23 seconds, the upper half part of the screen was masked (see Figs. 1(a) and 1(b)). These durations were selected during preliminar testings.

At the end of the experiment, the experimenter returned to the room and asked participants to complete the small questionnaire presented above. Finally, the experimenter explained to participants the real objective of the experiment (i.e., studying haptic features of a stressful affective state).

4 Results

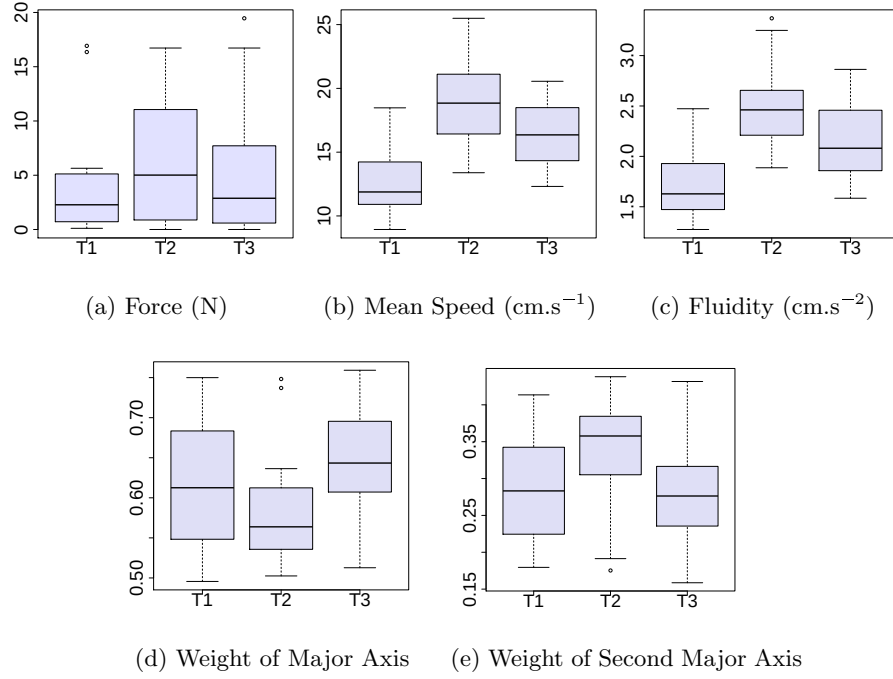
Figure 3 presents the measures computed from the collected haptic expressions for the three periods: before, during and after the stressful stimulus (**T1**, **T2** and **T3**). Table 1 presents the significant differences for these measures between the following pairs of periods: **T1** vs. **T2** and **T1** vs. **T3**.

Measures **M_{O1}**, **M_{O2}** and **M_{O3}** present a significant difference ($p < 0.05$, and a tendency for **M_{O5}**, $p = 0.0525$) between the periods before (**T1**) and during (**T2**) the stimulus. This supports **H2** for these measures. Measures **M_{O2}** and **M_{O3}** present a significant difference ($p < 0.05$, and a tendency for **M_{O4}**, $p = 0.0664$) between the periods before (**T1**) and after (**T3**) the stimulus. This supports **H3** for these measures.

Concerning subjective results, participants understood the task (**M_{S1}** = 5.00, SD = 0.00). They reported that they were not expecting the reduction of visibility (**M_{S2}** = 3.31, SD = 1.30). They also reported significantly they were less feeling controlling the task after the stimulus (**T3**) than before (**T1**) (**M_{S3}** = 4.50 VS **M_{S4}** = 3.75, $p\text{-value} = 0.0213$, $W = 78$). These results support **H1**.

5 Discussion and Conclusion

The above results show that for the exerted force, participants pressed more the button during the stimulus (**T2**), but the force returns to a normal level once the stimulus was stopped. Previous studies observed similar haptic behaviours in the case of frustration [10]. Thus, the increase of pressure seems to be a physical reaction to this kind of negative affective states. Participants used also

Fig. 3: Computed measures for the periods **T1**, **T2**, and **T3**.

Measure	Period during task:			Friedman (X^2)	Comparison: P-value (W)	
	T1	T2	T3		T1 VS T2	T1 VS T3
M1 Force N (SD)	4.13 (5.2)	6.35 (6.21)	5.04 (6.03)	0.00901 (9.42)	0.0319 (26)	0.979 (69)
M2 Mean Speed cm.s ⁻¹ (SD)	12.7 (2.59)	19.0 (3.17)	16.3 (2.46)	1.29e-6 (27.1)	0.000482 (0)	0.000482 (0)
M3 Fluidity cm.s ⁻² (SD)	1.17 (0.367)	2.50 (0.426)	2.16 (0.376)	1.22e-05 (22.6)	0.000584 (1)	0.000482 (0)
M4 Weight of Major Axis	0.613 (0.0785)	0.586 (0.0715)	0.647 (0.0730)	0.0339 (11.4)	0.518 (0.0715)	0.0664 (32)
M5 Weight of Second Major Axis	0.284 (0.0737)	0.340 (0.0768)	0.283 (0.0757)	0.0152 (8.38)	0.0525 (30)	0.856 (72)

Table 1: Mean values and standard deviation for each measure for **T1/T2/T3**. The two last columns compare the results: **T1** vs **T2** and **T1** vs **T3**.

less the left-right axis (i.e., the major axis) during the stimulus (**T2**). A possible explanation would be that their movements were jerkier as they moved the device faster to avoid obstacles. This might introduce useless movements in other axes than the left-right axis.

Participants' movements were both faster and varying a lot in speed during the stressful stimulus and even after. These variations were expected during the stimulus since the obstacles appeared at the last moment, forcing the participants to react quicker. However, this behavior was still active after the stimulus. As reported by some participants, they remain stressed after the stimulus as they thought that something else might happen again.

This study investigated spontaneous haptic behaviors occurring during stressed affective states. The proposed experimental design allowed to elicit stress in participants and to collect their haptic features. Haptic measures collected included both tactile (with force) and kinesthetic aspect of touch (with gestural patterns attended to be played-back for future perceptive studies). A possible application of these results would be the automatic recognition of stress in users' haptic behaviors. Future works will investigate if other participants would be able to perceive the change of behaviors in the collected haptic expressions. More precisely, if they are able to identify the affective nature of this change.

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