Whole-Body Haptic Feedback in Cinema

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Introduction

In recent years, haptic technologies have increased its presence in multiple fields, ranging from single purpose equip-ment to support people with disabilities [1] or to enhanceeducation [2], to general purpose devices. Smartphones area prime example in the last case, as they have evolved toinclude complex built-in haptic feedback, being one of themost iconic examples Apple, with its Taptic Engine and 3D Touch technology [3].

In this paper, the focus is laid on the entertainment field, where various attempts to include haptics have beencommited. For instance, the gaming industry, where the focusis on increasing the immersion of the user, has experiencedvarious haptic improvements throughout the years. One ofthe first haptic devices used was the Interactor Vest by AuraSystems [4] in 1994, which converted bass sound wavesinto vibrational feedback. In 1997 the first controller withvibrotactile feedback, Nintendo Rumble Pak, was released. Since then, it has been included in most video game console peripherals, thus becoming an essential feature. With therise of virtual reality and peripherals such as headsets, theinterest for developing haptic gloves and suits for the gaming industry has increased.

These have kept progressing since the Interactor Vest,experiencing a rise in development in the second decadeof the twenty first century, with the release of products such as the bHaptics vest [5], focused on videogames, orTeslasuit [6], which targets other fields, such as rehabilitationand training in multiple scenarios, ranging from hazardousand/or complex jobs to athletics.

Haptic suits have also been developed in the academia.One example is Force Jacket [7], an upper body haptic interface that aims to improve user's immersion in gamesand movies. Composed by a pneumatic actuation system in charge of controlling various air compartments, it's ableto apply localized pressure or vibration to the user, having been designed with various haptic effects, which ranged fromhuman interactions, such as hugs, to rain.

In cinema, there has been traditionally focus on the combination of image and audio, improving their quality in order to enhance the viewer's experience. However, as explained by Reiner [8], using haptics can noticeably increase the immersion of the user. There have already been attempts to create multisensory experiences involving touch, smell, taste and proprioception in cinema. One of the most iconic examples is Sensorama [9], introduced in 1962, where it waspossible to watch a movie while experiencing vibrations andodours. With regard to the sense of smell, its role in cinemahas changed over the years. From a negative influence atfirst, where the goal was to neutralize bad odours, evolvinginto its current passive role, Spence [10] discusses various experiments that aim to proceed to the next stage, where the sense of smell further enhances the experience. He also mentions the inclusion of the sense of taste with Edible Cinema [11], where the audience should consume sometreats in certain moments during the film.

There's been further research aiming to combine hapticsand cinema through various approaches. With regard towearables, in [12] a preliminary study focused on mood enhancement in films through a device, Mood glove, that applied vibrotactile feedback in both the dorsal and the palmareas of the hand.

A different approach is to deploy external hardware, instead of placing it on the user. In [13] deep learningwas applied to recognize scenes that fit into one of 4 environmental categories: glare, scorch, gale and cold. For each situation, there was a corresponding external feedback module controlled through Bluetooth. In [14], a VR360º video player with haptic feedback through a haptic chair is presented. This device consists of 6 voice coils arranged ina 3x2 grid with a subwoofer placed on the back of the chair, and another on the base.

One successful commercial solution in cinema is 4DXmultisensory technology [15], where the user can experience multiple effects, 21 in total, ranging from seat motion and vibrations to scents and environmental events such as rain.

Despite its various features, this technology offers limitedtactile feedback, focusing in that regard exclusively on theparts of the body in direct contact with the seat. Other areas, such as the chest, shoulders and some areas of the arm, areunable to experience any type of direct stimulation. Some of the before mentioned publications analyse the influence ofhaptic gloves in cinema, and others delve into haptic suitsfor other applications, but no noticeable work has been foundwhere customized, localized upper body haptic feedback isapplied in films for enhanced immersion. This paper aimsto perform a preliminary study on the perception of suchfeedback, synchronized with events taking place in a shortfilm. For that goal, the upper garment of a commercial hapticsuit, Teslasuit, is used.

Experimental Setup

Teslasuit was used to convey neuromuscular electric stimulation with pulse wave to the upper body of participants during the cinematic experience. Within the short movie, six physical interactions were set and the electric stimulation was triggered simultaneously, with the aim of enhancing plausibility. The haptic feedback system is built into the

smart textile of the suit which can be activated in response to actions or selected motions. The suit consists of two separate parts (jacket and trousers), but only the jacket was utilized in the perception test for reducing the calibration time foreach participant. Teslasuit's jacket, as seen in Fig. 1, has forty eight electro-stimulation channels. Eight haptic channels are located at the back, eight channels on the stomach area, twochannels at each shoulder, and fourteen channels at each arm.

Fig 1: Front and back views of Teslasuit jacket. The power unit is seenin the back view, placed on the lumbar area.

Haptic feedback was programmed using its software tool, Haptic Editor. The programmed haptic scenario was transmitted to the power unit of Teslasuit via Wi-fi connection. According to the haptic interactions taking place in the short film, every feedback channel was synchronized with the physical events one by one. Based on the preliminary tests, a 50 Hz pulse wave was found suitable for replicating the physical events. Therefore, the intensity and duration ofthe pulse wave were the parameters which were adjusted according to the haptical event. The sampling rate of theelectric stimulation was 1 kHz and the current of the signal varied between 20 mA and 50 mA, depending on theintensity of the electric stimulation. In addition, the overallintensity range of the stimulation signals was calibrated foreach participant individually due to the different perception sensitivities of the participants.

The visual content for conducting an experiment is 1minute long and includes six physical interactions to betranslated into haptic stimulation via Teslasuit. The synchronization between the visual scenes and the haptic feedback was done prior to the experiment, by playing the video frameby frame, and setting the haptic feedback timings according to the physical interactions. The short film consists of the following scenes. It begins with the main character sittingin his office in the afternoon. He proceeds to look at his wrist watch by pulling his shirt slightly off (1), deciding afterwards to leave the office. In this scene, the haptic feedback is considered to be tingling, rather than a strong stimulation on the left front arm. Following that, he puts his jacket on (2), followed by the backpack, which is placed onhis back (3). When the actor is wearing the jacket, thirty two channels at the left arm, right arm and shoulders of the suit were stimulated while eight channels at the back area of the suit were stimulated for the backpack scene.

For these three stimulations, eah one is 1.5 timesstronger/more powerful than the previous one, being the thirdin that way due to the weight of the backpack. After the thirdevent, he locks the office door and begins walking whilechecking his mobile phone. After a short while, he collidesaccidentally with his colleague on the corridor (4). Due to thecollision, the fourth stimulation is considered to be the mostintensive haptic feedback located on the left shoulder forshocking effect, being twice as powerful as the third signal. At the end, they greet each other and exchange a few words, hugging each other (5, 6) and leaving shortly after separately.In these scenes, the haptic feedback was given through fourchannels on the back. The feedback at the fifth and the sixth scenes are considered to be as intensive as the second and the third stimulations.

Experimental Method

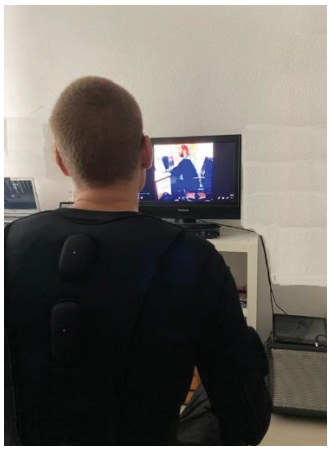

Fig 2: The participant while watching the short film with Tesla jacket.

In this study, after watching the short film without and withhaptic feedback, the participants completed a questionnaireand two perceptual tests (similarity and plausibility estima-tions). The questionnaire consists of two questions with the two alternative forced-choice method and a comment section. The questions are "Would you prefer body-haptic feedback during the movies?" and "Does haptic feedback make you interact more with the short film?". The participants had to select either "Yes" or "No". At the similarity evaluation part, the subjects were requested to rate the realism ofhaptic feedback compared to the physical events based on the Rohrmann scale method using verbal labels. The verbal labels were "not at all", "little bit", "middle", "very much"and "fully", placed on the continuous equal interval scalefrom 0 to 100 at the experiment interface. The subjects could also scale anywhere in between two labels using the slider. At the plausibility estimation part, the subjects were requested to rate the plausibility magnitude of the haptic cinematic experience (trimodal case) with respect to the cinematic experience without haptic feedback (bimodal case).For instance, if the perceived haptic cinematic experienceis twice more plausible than the reference stimulus which isassumed as 100, the subjects would assign 200. On the

otherhand, if the haptic experience is twice less plausible, thenthey would assign 50. The rankings of 100 corresponds tothe similar magnitude of plausibility in perceptual dimension.This judgment was conducted on linearly proportional scale.

In total, 9 subjects, 5 males and 4 females aged between 24 and 39 years, participated in the experiment. The participants declared their consent to attend to the experiment after theywere informed about the experiments and any possible risks.

Results

In the perceptual test, the plausibility of the cinematic experience with haptic feedback, the similarity of hapticfeedback with respect to physical events and binary qualitative questionnaires were judged by the subjects. The data for magnitude estimation and similarity evaluation werenormally distributed. Since the test was done based on only two stimulus (watching the short film with and without haptic feedback), ratings of evaluations are plotted in the samegraph as seen in Fig. 3. In the figure, it is observed that thereare distinct differences between the plausibility magnitude oftrimodal and bimodal stimulus. However, the haptic sensation was felt barely similar with respect to physical events.

The mean magnitude value of the plausibility of trimodal condition is 149.5 and the standart deviation is 17.08. Moreover, according to t-test (two independent sample test), the trimodal stimulus was found significantly different than bimodal stimulus (p=.002). It shows that adding haptic feedback to the short film increased the perceived plausibility of cinematic experience. The mean score of similarity ratings of haptic sensation is 38.84 and the standard deviation is10.95. These values show that subjects tend to select theverbal label of middle in terms of the similarity between the haptic feedback and the physical events. The reason can be that the subjects had the difficulty to imagine the physical events. In addition, they might have thought that the sensation of electro-vibration signal did not fit to thephysical events.

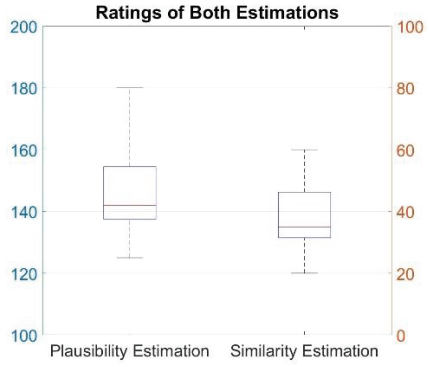

Fig 3: Plausibility estimation test was conducted based on magnitude scaling method while similarity estimation was conducted based on Rohrmann scaling method. Experimental result of plausibility test is seen on the left, the result of similarity test on the right.

For the first question, seven subjects selected ”Yes” and two subject selected ”No”. The real possibility of preferring haptic feedback with films is 77% (Margin of error = 22%with the confidence level 90%). For the second question, eight subjects selected ”Yes” and one subject selected ”No”.The possibility of which the subjects interacted with the short film more thanks to haptic feedback is 88% (Margin oferror=17% with the confidence level of 90%). According to the chi-square test with the measure of association of Phi(φ),a significant correlation is detected between the answers ofthe first and second question (p=0.047). In other words, the subjects liked the augmented reality of the short film, and this affected their preference at the first question. Please notethat since the experimental data is not big enough due torestrictions during the global pandemic, statistical analysis ofthe questionnaire was conducted based on 90% confidence interval for smaller margin of error.

Discussion

In this study, the effect of enabling haptic feedback inthe cinematic experience was evaluated. During the shortfilm, haptic feedback was driven along a sequence of six different physical events. The goal of this study was to testif the use of a wearable haptic jacket can contribute to the enhancement of the cinematic experience. This assumption was made considering the fact that additional modalities might let the user interact with the virtual environment more intuitively. The counter argument was that watching a film ora video is a passive event as opposed to gaming applications. In video games, the user controls the virtual environmentas the main character, and haptic feedback has been found successful to enhance the immersion. On the other hand, rendering physical events in movies is indeed similar to itscounterpart in video games, due to the aim of providing amore immersive experience. The crucial issue that should betaken into account is the influence of the camera’s angle and character’s orientation, which may change from one scene to another, or may even happen in the same scene.

This aspect, which may be confusing for the audience, should be carefully analysed, and reveals an important difference between videogames and cinema: The viewer’s perspective. As mentioned before, in videogames the player is usually focused on one character at a time, thereby, having a continuous experience without considerable disruptions. On the other hand, cinema frequently presents a more dynamic visual experience, continuously interchanging scenes and modifying the viewers perspective and observations, as there are frequently multiple characters involved. There are, however, movies explicitly created for their visualization with VR headsets, where the user experiences a continuous experience with smooth transitions, where additional haptic feedback can be advantageous. Therefore, viewers should beinformed beforehand whether haptic feedback is driven ona wearable haptic garment according to the relative body direction of the main character, or with regard to the relative direction of the screen.

Regarding to the collected magnitude estimation ratings,the trimodal cinematic experience was found

significantly different than the bimodal case. In other words, providing haptic feedback in order to let the subjects feel thephysical actions of the main character increased the overal lplausibility of the short movie with a confidence intervallevel of 95. Therefore, it can be said that applying haptic feedback can make the audience interact more with the main character in a movie. On the other hand, the ratings ofthe similarity evaluation demonstrates that the sensation of electro-stimulation did not perfectly match with the observed physical events. The reasons may be that translating multi-sensory physical events exclusively into electro-vibrational stimulation might be perceived limited despite that the inten-sity level was adjusted separately for every event. As one ofthe subjects reported, the similarity between the stimulation and the observed physical events was different for everyevent. In particular, the collision effects at the scenes of wearing backpack and the colliding with someone were theleast similar effects. The events 1, 2, 5 and 6 were less intense than the events 3 and 4, and they were considered to be tingling sensation. However, the third and the fourth events were planned to be stronger stimulations in order to provide a collision feeling. However, these stimulations might have resembled the feeling of electric shock rather than an ordinary collision sensation, which could be annoying and undesired. Therefore, collision sensation is the crucial partfor reproducing physical events using TeslaSuit in cinematic experience.

Moreover, collected answers from the questionnaire showed that the majority of the participants agreed with the positive influence of haptic feedback while watching theshort film. Certainly, this result does not prove in general terms that cinema can be more entertaining/influential withthe presence of haptic feedback, since cinema is not only intended to entertain the audience, but also to make viewers imagine, question, learn etc. Nevertheless, some participants pointed out that providing haptic feedback may improve significantly the experience for action and horror movies. It indicates, as mentioned previously, that if the audience imagines itself as the main character, haptic sensations maycause the cinematic experience to be a more plausible andintuitive event.

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