Get Your Virtual Hands Off Me! - Developing Threatening IVAs Using Haptic Feedback

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Abstract. Intelligent Virtual Agents (IVAs) become widely used for numerous applications, varying from healthcare decision support to communication training. In several of such applications, it is useful if IVAs have the ability to take a negative stance towards the user, for instance for anti-bullying or conflict management training. However, the believability of such 'virtual bad guys' is often limited, since they are non-consequential, i.e., are unable to apply serious sanctions to users. To improve this situation, this research explores the potential of endowing IVAs with the ability to provide haptic feedback. This was realized by conducting an experiment in which users interact with a virtual agent that is able to physically 'touch' the user via a haptic gaming vest. The effect on the loudness of the speech and the subjective experience of the participants was measured. Results of the experiment suggest there might be an effect on the subjective experience of the participants and the loudness of their speech. Statistical analysis, however, shows no significant effect but due to the relatively small sample size it is advisable to further look into these aspects.

1 Introduction

Intelligent Virtual Agents (IVAs) are intelligent digital interactive characters that can communicate with humans and other agents using natural human modalities like facial expressions, speech, gestures and movement [19]. Recently, IVAs have become widely used for numerous applications, varying from healthcare decision support [8] to communication training [20]. In such applications, IVAs play various roles in which they interact with users, for instance as an instructor, therapist or teammate [15].

In the vast majority of these cases, IVAs are friendly and supportive towards the user. Instead, there was less attention for IVAs with a 'negative' or 'aggressive' attitude towards users (i.e., 'virtual bad guys'). This could be considered a missed opportunity, since the concept of virtual bad guys opens up a range of useful applications. Examples include virtual training of aggression de-escalation skills [6], anti-bullying education [23], and Virtual Reality exposure therapy [16].

However, a common difficulty in the design of IVAs is to make them *believable*, i.e., to provide the illusion of being alive [2]. This poses a particular challenge for 'virtual bad guys', since effective applications involving aggressive agents require that users feel indeed seriously threatened or stressed by the IVA. However, IVAs are typically non-consequential, i.e., they are unable to apply serious sanctions to (or even physically harm) their human interlocutors. As a result, users still perceive IVAs as rather artificial beings, which possibly also influences the way they interact with them.

Triggered by this insight, the question addressed in this paper is how to develop aggressive virtual agents that are taken seriously. This question is tackled by designing and experimentally examining the effects of a threatening IVA that is able to physically 'touch' users by means of haptic feedback, which is realized by means of a haptic gaming vest. More specifically, we investigate whether endowing an IVA with the ability to provide such a physical threat has an impact on the verbal behaviour of users as well as their subjective experience.

The remainder of this article is structured as follows. In Section 2, the recent literature on aggressive virtual agents and on haptic feedback is reviewed. Next, in Section 3 the design of the performed experiment is presented, and the results are provided in Section 4. These results are evaluated in detail in Section 5. A conclusion is provided in Section 6, and Section 7 completes the paper with a discussion.

2 Related Work

The relevant literature for this project covers two main areas, namely aggressive virtual agents and virtual touch. The state-of-the art in these two areas is discussed in the following sub-sections.

2.1 Aggressive Virtual Agents

Research on emotions within IVAs has received much attention in recent years. An important stream of research addresses the development of generic computational models of emotion [12]. Probably the most influential approach is EMA [13], a computational model that formalises the main assumptions behind appraisal theory [11]. Although such models could be used to have agents generate emotional states like 'angry', they do not focus on agents that take a threatening attitude towards humans.

Instead, other research has focused more explicitly on the impact of emotional agents on humans in interpersonal settings. For example, the Sensitive Artificial Listener paradigm enables studying the effect of agents with different personalities on human interlocutors, which provided evidence that IVAs with an angry attitude indeed trigger different (subjective and behavioural) responses than agents with other personalities [17]. Similarly, a study in the domain of negotiation led to the conclusion that IVAs expressing anger (in terms of utterances and facial expressions) lead human negotiation partners to make larger concessions [7]. Another recent study pointed out that a virtual agent that made an 'outburst of aggression' (in terms of shouting to and insulting the user) was able to trigger increased physiological responses [5].

Nevertheless, as also concluded in [5], these responses are still insufficiently strong to be really useful for effective applications where heavy emotional stimuli play a role, such as aggression de-escalation training systems for law enforcement personnel [9] or public transport employees [6]. The assumption underlying the current paper is that this is due to the inability of existing IVAs to apply serious (e.g., physical) sanctions to human interlocutors. This is in line with research in the domain of shooting behaviour training for police officers, which indicates that 'simulated threat' is a necessary criterion to realize an adequate transfer of training from the simulated to the real world [14].

Hence, the current paper aims to bring interactions between humans and aggressive virtual agents to a next level of realism, which is done by introducing two technological innovations, namely immersive Virtual Reality and haptic feedback.

2.2 Virtual Touch

The domain of virtual reality is seeing its technology applied in fields like entertainment, education and even medicine. One of these applications is virtual reality-based training, which can be used for various purposes. In order for the effects of such training applications to be applied in the physical world it is important that the scenarios used resemble this world as closely as possible. This way users are offered an experience as if they were in the physical world itself.

Since a number of years, virtual reality applications are combined with haptic feedback, enabling users to 'touch' objects in the simulated environment. Most of these applications focus on touching static objects rather than conversational agents, for instance for surgical training (e.g., to improve performance in cadaver temporal bone dissection) [22].

Recently, virtual touch is also applied in a more social setting, leading to the area of 'virtual interpersonal touch' (e.g., [1]). For instance, research by Cheok and colleagues explores the use of haptic technology to reproduce multi-sensory sensations related to intimate activities like kissing [21] and hugging [18]. Although the primary use of such technology was to enable intimate touch sensations between humans remotely, it is also claimed to have potential in the area of human-agent interaction. Similarly, other researchers have studied the use of social touch with the aim to make virtual agents more 'warm' or empathic (e.g., [4], [10]). Nevertheless, all of these developments are in the context of 'positive interpersonal touch'. As far as could be determined, research into virtual agents that may touch human conversation partners with the purpose of intimidating or threatening them is still in its infancy.

3 Method

To investigate the effect of touch by a threatening virtual agent on human participants, the following experiment was set up. Participants were asked to interact with a virtual agent in a virtual reality environment through free speech. At some point during this interaction, the virtual agent would start threatening the user, which was followed by a 'push' that was simulated through haptic feedback. A haptic gaming vest was chosen, because this enabled the users to be provided with a serious physical stimulus, while avoiding physically harming them (which would be the case by using for instance electric surges), which obviously is ethically irresponsible. This section describes the experimental set-up in detail.

3.1 Participants

A convenience sample of 47 people was recruited, most of which were academic students. The age of the participants varied between 18 and 25 years. Participants were randomly assigned to the experimental group that received haptic feedback or the control group that did not receive any feedback. The experimental group consisted of 21 participants (12 male, 9 female), and the control group consisted of 23 participants (13 male, 10 female). Three runs of the experiment resulted in corrupted or incomplete data and so these have been removed.

3.2 Experimental design

Participants were placed in either a condition with haptic feedback during the interaction (condition A) or a condition without haptic feedback (condition B). In both conditions, participants were wearing the haptic feedback equipment (as to eliminate any effects of the equipment itself), but they were not told in advance what was the purpose of the equipment. In the control condition, the haptic vest was turned off, but the participants did not know this.

The experiment used a between-participants design (where each participant is only allocated to one condition) instead of a within-participants design (where each participant would experience both conditions sequentially), because in the latter case, the participants would already expect the virtual push after having experienced the scenario once.

3.3 Tasks

The participants were asked to engage in a virtual reality scenario (displayed on a Head Mounted Display) taking place in the context of a nightclub in which they can freely move around. The participants were tasked with finding the bathroom in the virtual environment, after which they were to return to the bar area they initially started in and have a drink with their friend. However, on their way to the bathroom the participants would encounter a virtual agent named Mason. Mason poses the threat in the virtual environment by acting very aggressively towards the participants. As they walk through the corridor towards Mason, he walks into them and so spills his drink. This sets up a situation in which the agent behaves aggressively towards the users and at some point even physically 'attacks' the user. This attack has the form of a push which is transferred to the user through the haptic feedback vest.

Throughout the nightclub several virtual agents can be seen and heard interacting with each other. The users can only interact with two of the agents in the scenario through free speech responses during a conversation. The first agent they encounter is used to make the participants more comfortable with the free speech interaction paradigm. The second agent, Mason, is used to analyse the responses of the participant. Both agents have been created in such a way that they always give the same responses, no matter what the user says. This was done to minimize the differences across individual trials.

The responses of virtual agent Mason have been inspired by the Sensitive Artificial Listener paradigm [17], which enables users to interact with virtual agents using free speech. The dialogue can be set-up in such a way that the agent always seems to respond to what the user says even if this is not the case and the agent just follows a script.

During the conversation with Mason the participants were free to respond in whatever way they saw fit. Participants were only limited in that they should speak loud and clear, always respond to the agent and use at least one full sentence to respond. The conversation consists of ten user responses which results in a select set of data to analyse. To this end, participants were asked to respond at all times. The participants were alerted to the fact that the microphone might not pick up their voice if they did not speak loud and clear and this would result in difficulties for the analysis of the data.

Both conversations in the scenario are turn-based, meaning that both the agent and the participant take turns while speaking. Only the agents can initiate conversations as to avoid the participants trying to start a conversation with every agent they encounter.

3.4 Variables

Two types of dependent variables were used in this study, namely subjective and objective variables. As subjective variable, the participants' experience was measured through a questionnaire they had to fill in at the end of the experiment. This questionnaire contained the following questions, which had to be answered using a 5-point Likert scale (from 'not at all' to 'very much'):

- Q1 Did you have any experience with the use of head mounted display devices prior to this experiment?
- Q2 Did you have any experience with the use of haptic feedback hardware prior to this experiment?
- Q3 Did you find the virtual scenario to be realistic?
- Q4 Did you find Mason to be aggressive?
- Q5 Did you find Mason to be threatening?

In addition, the following yes-no questions were used:

- Q6 Were you startled when Mason pushed you?
- Q7 Did you look at Mason when he pushed you?
- Q8 Did you first walk through the club before talking to Mason?
- Q9 Did you react differently to Mason after he pushed you?

Some of these questions (Q1, Q2, Q7, Q8) were used as control questions, to avoid that any differences found could be attributed to other factors. For the other questions, the aim was to investigate *whether people have a more intense experience in the condition with haptic feedback than in the condition without* (Research Question 1).

The objective variable that was studied was the verbal behaviour of the participants during the interaction with Mason. More specifically, we used the loudness of their speech as an indicator for the participants' engagement in the scenario, as people who are excited typically speak louder [3]. The relevant data for this were obtained through the use of a web cam that recorded the experiment session. The audio from the recordings was extracted and the amplitudes from the audio files were sampled. This way it could be analysed whether the participants spoke louder or softer after being pushed in the virtual scenario. Hence, the aim was to investigate *if people use louder speech in the condition with haptic feedback than in the condition without* (Research Question 2).

3.5 Material and facilities

The experiment has been conducted in a quiet room in which only the participant and experimenter were present. This room contained a desk with the computer that hosted the virtual environment, a four-legged chair for the participants to sit on during the experiment and a desk with the equipment used during the experiment. The chair on which the participants took place was selected not to be an office chair, as these chairs can turn. When the participant is using the Head Mounted Display to look around in the virtual environment sitting on an office chair would mean they would be able to look behind themselves in the environment while their virtual body would still be facing the other way.

The Virtual Environment was presented to the user using a Head Mounted Display, in this case the Oculus Rift Developer Kit (version 2)[1]. Using an advanced high-quality Virtual Environment and a Head Mounted Display requires a high-end gaming computer with a high-end graphics card to ensure smooth performance for an optimally effective Virtual Environment. The computer used an Intel i7-4630 CPU with 16GB DDR4 memory, a 500GB SSD and a Nvidia GTX-780 graphics card with 1GB of memory. To facilitate the haptic feedback a so-called gaming vest was used (the KOR-FX[2]). These vests incorporate vibration motors that mimic physical impact to the torso. The KOR-FX vest uses two large vibration motors, one on left side of the chest and one on the right side. The vest is wirelessly connected to a control box. This control box accepts low-voltage input (0-5V) and is meant to accept standard sound output of the sound card of a computer. To gain complete control over the haptic feedback, an Arduino One board[3] has been used with an analogue line (0-5V) as output to the KOR-FX controller box. The Arduino accepted commands from the Virtual

[1] https://www3.oculus.com/en-us/dk2/
[2] http://korfx.com/
[3] https://www.arduino.cc/en/Main/ArduinoBoardUno/

Environment, via the USB connection to the computer, to activate the vibration motors in the gaming vest. This way the Virtual Environment had complete control over the haptic feedback to the participants. The Arduino also used a microphone that recorded the volume level of the sound in the environment, i.e. the voice of the participant. The microphone polled from a script inside the Virtual Environment to monitor the speech of the participant. A standard USB game controller was used to control the virtual agent of the user. See Figure 1 for an overview of the system's architecture.

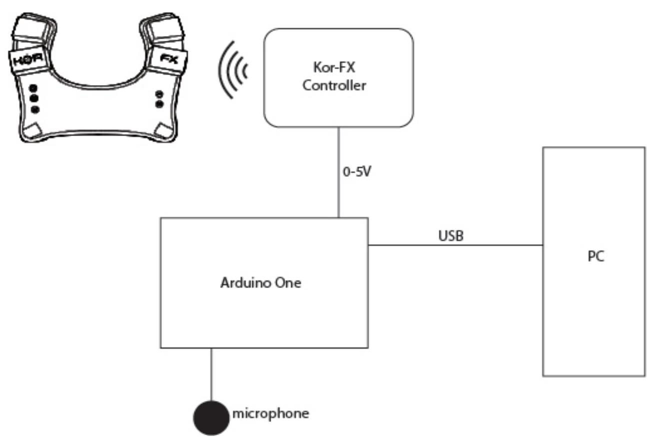

Fig. 1. System architecture.

3.6 Virtual Environment

The Virtual Environment has been developed in Unity Pro (version 5)[4]. A ready-made model from the Unity Asset Store has been purchased for the club environment that has been used in the experiment. This model has been further adapted in order to suit the needs of this research. Atmosphere was added by including special lighting and additional props on the virtual stage. All the humanoid agents in the Virtual Environment have been generated using the iClone Pipeline software (version 6)[5]. The Character Creator[6] has been used to generate realistic and unique human agents. iClone itself has been used to create the body animations and lip-sync movements.

3DXchange[7] has been used to convert the agents including their animations into FBX format that could be imported into Unity Pro. Inside Unity

[4]https://unity3d.com/

[5]http://www.reallusion.com/iclone/default.html

[6]http://www.reallusion.com/iclone/character-creator/default.html

[7]http://www.reallusion.com/iclone/3DXchange.html

Pro the non-interactive characters were scripted using C#, looping animations and speech to create a livelier atmosphere in the club. The interactive agents, the character in the role of the friend of the participant and Mason, have been separately scripted for more advanced actions. These two agents had a larger set of animations and speech, plus the ability to react to speech of the participants. The agent would monitor if the participant was speaking. If the participants did speak the agent would wait until the participant stopped, allowing for small pauses in speech (of 1 second), or until a maximum amount of time (of 10 seconds) had elapsed. This produced a more realistic reaction of the agent.

Additional scripts made sure that once the participant entered the hallway to the toilets, an encounter with Mason was unavoidable. Both speed and direction of movement of the avatar of the participant were taken over by the script so that the participant and Mason would end up directly in front of each other. A screenshot of the application is shown in Figure 2.

Fig. 2. Screenshot of the application.

3.7 Procedure

After entering the room the participants were asked to sign an informed consent form, allowing for the gathered data to be saved and used for the duration of the research project. Participants also read the health and safety warnings for the Oculus Rift and KOR-FX gaming vest to be able to indicate whether they could safely work with this equipment.

Next, the participants read the experiment instructions and put on the KOR-FX gaming vest. They would take their seat behind the computer and the experimenter would inform them of the instructions once more, highlighting the importance of speaking loud and clear, always responding and using at least one whole sentence to respond with. If the participants had no further questions they put on the Oculus Rift and the experimenter started a tutorial scenario. In this scenario participants could walk around in order to get accustomed to the controls. The scenario is a grey plain with several blocks placed on it for orientation purposes. The 'ceiling' of the scenario is a sky with a sun. When the participant indicated to understand the controls the experimenter started the recording and the virtual scenario in which all interactions took place.

The participants interacted with the first agent in the environment and then moved on to find the bathroom as instructed. After completing their conversation with virtual agent Mason the screen faded to black and the experimenter stopped the recording. All equipment used was removed and the participant was asked to fill in the questionnaire on the computer. During this the experimenter did not answer any questions the participants had, nor respond to any of their remarks regarding the experiment as not to influence their answers to the questionnaire. For their participation in the experiment, participants were rewarded with a sweet roll after completion of all tasks.

4 Results

This section describes the results of the experiment in detail. First, the subjective measures will be presented, followed by the objective measures.

4.1 Subjective Measures

Figure 3 shows the means of the answers given by the participants to the Likert-scale questions. For example, in condition A (the condition in which haptic feedback was received), the mean of the answers to the question regarding experience with head mounted display devices was 2.33, whereas for condition B it was 2.00.

To analyse whether there was a significant difference between the two conditions regarding the mean answers that were provided to the Likert-scale questions, unpaired t-tests have been performed, under the assumption that the scales reflect continuous data. The results of these tests are displayed in Table 1.

Table 1. T-test results on Likert questions (significance level = 0.05).

Question	P-value	Significant difference
Q1 (HMD experience)	0.37	No
Q2 (haptics experience)	0.62	No
Q3 (scenario realistic)	0.12	No
Q4 (agent aggressive)	0.76	No
Q5 (agent threatening)	0.73	No

Figure 4 displays the results for the yes-no questions for condition A and B, respectively. As an illustration, The figure shows that in condition A, 13

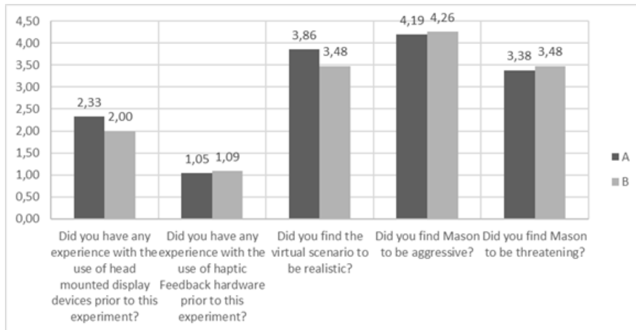

Fig. 3. Answers to the Likert-scale questions.

participants gave a positive answer to Question 6 ('Were you startled when Mason pushed you?'), whereas 8 participants gave a negative answer. Instead, in condition B, 8 participants gave a positive answer to this question, and 15 participants gave a negative answer.

To analyse whether there was a significant difference between the two conditions regarding the answers that were provided, a series of Chi-square tests have been performed. The results of these Chi-square tests are displayed in Table 2.

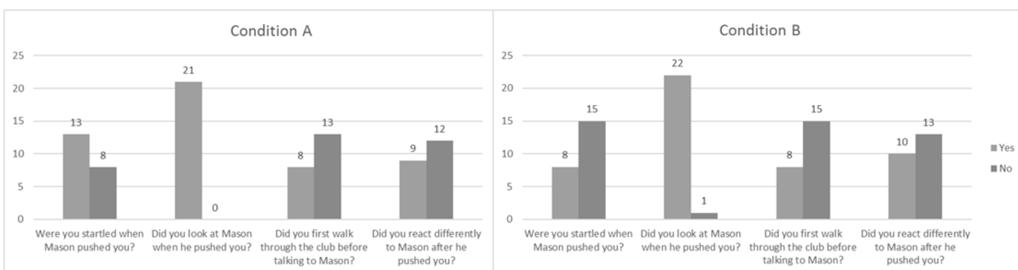

Fig. 4. Answers to yes-no questions for condition A (with haptic feedback) and B (without haptic feedback).

Table 2. Chi-square test results on yes-no questions (significance level = 0.05).

Question	Chi-square value	Variable independence
Q6 (startled by push)	0.07	Yes
Q7 (looked at agent)	0.79	Yes
Q8 (walked around)	0.99	Yes
Q9 (different after push)	0.99	Yes

4.2 Objective Measures

Objective data were obtained by analysis of the audio recording of the experiment sessions. From the audio files, obtained during the experiment sessions using a web cam, the amplitudes of the speech sample concerned with the conversation with Mason have been extracted using Audacity[8], an audio editing tool. These data were then processed using a script written in Python 2.7 in order to obtain the mean amplitude of the utterances prior to the haptic feedback event (i.e., the virtual push) and of the utterances after the event. This was done to determine whether participants spoke louder or softer after being pushed. A summary of the results is presented in Table 3.

Table 3. Comparison of speech volume before and after the virtual push.

Condition	Louder	Softer
A (haptic feedback)	15	6
B (no haptic feedback)	10	13

Statistical analysis of these data was performed again using Chi-square tests. The Chi-square value of this test was 0.06.

5 Evaluation

In this section the results that have been presented in the previous section will be evaluated in the context of the original research questions. First, the subjective results will be evaluated (Research Question 1) and thereafter the objective results (Research Question 2). Finally, a brief follow-up experiment is described, along with its results.

5.1 Research Question 1

Table 1 shows there is no significant difference between the ratings for prior experience between the experimental and control group (Q1 and Q2). The fact that there is no significant difference between the two groups in the level of experience with any of the devices used, indicates that any effect that is found can not be contributed to this.

There was also no significant difference found between how aggressive (Q4) or threatening (Q5) the participants perceived virtual agent Mason to be. Neither was there any difference between how realistic the experience was for the participants (Q3). This would indicate that the haptic feedback that was provided to participants in condition A did not affect any of these factors. Participants in the control group have indicated to have had almost the same experience as those participants that did receive haptic feedback.

[8]http://www.audacityteam.org/

The Chi-square tests applied on the yes-no questions, displayed in Table 2, show that there is variable independence between the experimental group to which the participants were allocated (A or B) and their answers to these questions. This means that the group in which the participants were placed did not affect their answer to these questions. Therefore, on the one hand, any effect of the haptic feedback cannot be attributed to some of the participants looking at Mason and others looking away (Q7) or some participants walking around in the environment first and others heading straight for their goal (Q8). On the other hand, this also means that no effect of haptic feedback on the reaction of the participants (Q9) or them being startled by the virtual push (Q6) is found.

However, the statistical test performed to determine variable independence between participants being startled and receiving haptic feedback returned a P-value of 0.07. In addition, several people in the haptic feedback condition mentioned that they found the feedback experience at least 'surprising'. As this was an experiment with a relatively low number of participants (44) and the significance value used for this test was 0.05, it is advisable to perform a second experiment with a larger sample size in order to determine whether there is actually no correlation between participants receiving haptic feedback and being startled by the virtual agent.

5.2 Research Question 2

The data obtained after processing of the audio files seem to suggest that participants that received haptic feedback on average spoke louder after receiving this feedback compared to participants in the control group. However, the Chi-square test shows variable independence, indicating that the pattern could be obtained through chance. Just as with the subjective data regarding the startling of participants it is important to remark that the Chi-square value is 0.06. Therefore, it would be advisable to perform a second experiment with a larger sample size in order to determine whether there actually is no pattern between loudness of speech and the application of haptic feedback.

5.3 Follow-up Experiment

In order to investigate the effect of haptic feedback on the experience of being startled (Q6) with a (slightly) larger sample, ten additional participants performed the experiment at a later date. Due to problems with the equipment, this follow-up experiment could not be conducted for the objective measures. Since a second analysis of the data would be performed (including the data from the first 44 participants) the significance level was adjusted to 0.025, under the assumption that adding more participants would otherwise always lead to some kind of significant effect.

Analysing the subjective data regarding the startling effect for all 54 participants yielded the results presented in Table 4. After increasing the number of participants, there still seems to be no significant effect of startling. On the contrary: the Chi-square value has increased from 0.07 to 0.1.

Table 4. Chi-square test results on question Q6 (54 participants, significance level = 0.025).

Condition	Yes	No
A (haptic feedback)	15	12
B (no haptic feedback)	9	18
Question	Chi-square value	Variable independence
Q6 (startled by push)	0.1	Yes

6 Conclusion

In this research the effects of negative haptic feedback in the form of a 'push' by a virtual agent in a threatening scenario are explored. To this end an experiment was set-up featuring 44 participants, distributed over two conditions. During this experiment participants interacted with two virtual agents through free speech in a virtual environment. For this an Oculus Rift and the KOR-FX gaming vest have been used. Participants in the experimental group received haptic feedback, through vibrations created by the KOR-FX vest, at a certain point during their conversation with one of the virtual agents. At this moment in the conversation the participants were being attacked by the virtual agent in the form of a push that was synchronised with the haptic feedback that was received. The participants in the control group also used both the Oculus Rift and the KOR-FX vest, but did not receive haptic feedback during their interactions with the virtual agent.

Subjective data were obtained from a questionnaire that was filled in by participants after the experiment had been completed. Objective data were obtained through a recording of the experiment session using a web cam. The audio recording of the experiment was analysed in order to determine the loudness of speech of the participants prior to- and after the haptic feedback event.

Statistical tests indicate that haptic feedback did not have any effect on the experience of the participants in this scenario for the measured variables. The Chi-square test that was performed on the loudness of speech resulted in a value of 0.06, which was close to the significance level of 0.05. In the questionnaire participants were asked whether they were startled when they were pushed in the scenario. The statistical test performed on these answers resulted in a Chi-square value of 0.07 for a significance level of 0.05. As this study featured 44 participants, ten additional participants performed the experiment in order to gain better insight in the near-significant effects. A second statistical analysis of the subjective data for the startling effect resulted in a value of 0.1. As a consequence, no significant effects of the haptic feedback could be demonstrated on the various subjective aspects (Research Question 1) and objective aspects (Research Question 2) measured.

7 Discussion

Despite the fact that no statistically significant effects of haptic feedback were found, this research provides several useful pointers for follow-up research. First of all, the fact that no effect on subjective experience could be demonstrated might be related to the particular set-up of the experiment, which used a relatively low number of participants, and a between-participants design. Since participants played the scenario only once, they had no frame of reference to which they could compare their experience, which made their Likert-scale response difficult to interpret. It might be the case that if participants would experience both conditions (with and without haptic feedback), they would still feel a big difference between them. This is a common problem in user experience research, and it is worthwhile to explore this in more detail.

Secondly, although this research has explored the effect of negative haptic feedback on several aspects of the experience of the user, it has not been exhaustive in that regard. Future research might look into the effect on loudness of speech using more participants in order to ascertain whether haptic feedback might have an effect or not. Other considerations for future research might include alternative ways in which negative haptic feedback influences user experience, the role of the intensity of the feedback (possibly up to the point where the feedback actually hurts), and providing haptic feedback multiple times.

All in all, it is concluded that the lack of significant effects found in the present study should rather be explained by the specific design of this experiment than by the paradigm as a whole, and that follow-up research is required to investigate the full potential of threatening virtual agents based on haptic feedback.

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