ABSTRACT
Virtual Reality (VR) has been used to alleviate pain for different types of patients. This VR experience can elicit immersive presence, a state in which the senses of the users are engaged, and therefore they perceive less pain. This research investigates if laughter can influence immersive presence, by conducting an experiment in which subjects experience VR with or without laughter. This research has found a significant increase in immersive presence after exposure to the laughter VR condition. Laughter has been found to influence immersive presence. A positive relation between laughter and immersive presence could improve the efficacy of Virtual Reality in a pain management context.

Keywords
Virtual reality, immersion, presence, pain, laughter, joyful, happiness.

1. INTRODUCTION
Virtual Reality (VR) has shown to influence pain, defined as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage [International Association for the Study of Pain]", in several types of patients: e.g. burn, cancer, pediatrics or during routine checkups [7, 9, 10, 12]. VR can affect the perceived pain levels of the patient by influencing their immersive presence (immersion), defined as a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with a virtual environment [23]. A state in which the senses of the user are engaged by Virtual Reality. Immersive presence alleviates the pain levels of the patient by engaging their senses in the VR. This engagement allows patients to experience the VR as if they were in the virtual environment and therefore not in their pain-stricken reality.

As immersive presence engages the patients' senses, it is necessary to have a VR experience that increases immersive presence to aid in pain management. Higher immersion will result in a higher engagement of senses and therefore increasing the pain alleviating effects [13]. To achieve higher levels of immersive presence, we used an emotion as stimulus. Laughter has been found to be able to communicate different emotions, e.g. joy, taunt [21]. As a positive correlation between positive emotions and presence exists [16], we select joyful laughter as stimulus. This type of laughter represents the emotion joy, a positive emotional state.

In this research, we measure the level of immersive presence after exposure to laughter VR and non-laughter VR.

1.1 Research goal and questions
The main goal of this research is to find out if laughter affected immersive presence in VR. Having a known factor that influences immersive presence, could enhance an immersive VR experience and increase its immersive potential.

This research goal can be achieved by answering the following research questions:

- **RQ1:** Does laughter influence immersive presence in a VR context?
- **RQ2:** Does VR with laughter influence immersive presence more than VR without laughter?

2. RELATED WORK AND BACKGROUND
2.1 VR as pain management tool
The effect of VR in the context of pain management had been studied widely [7, 9, 10, 12, 13, 22]. Studies had applied different definitions or used other terms for their employed definition of immersion, e.g. presence, distractive VR. Slater defined a more objective description of immersion, as the extent of the technology that delivers a surrounding environment, one which shuts out sensations from the 'real world' and they defined presence as a more subjective experience, as the 'sense' of being in the VR, the extent to which the VR becomes dominant and the experience that users remember it as having visited a 'place' instead of computer generated images [20]. Witmer & Singer defined immersion as mentioned in section 1 and presence was defined as the subjective experience of being in one place or environment, even when one is physically situated in another [23]. They also stated that immersion is linked to presence, as greater sense of immersion will produce higher levels of presence. It depends on the used definition if you argue that presence (Slater) or immersion influencing presence (Witmer & Singer) effects the amount of pain relieve with VR use. In this research the definition "immersive presence" is used, as it encompasses the general intention of the different definitions in these studies. Which is the alleviating pain by engaging senses, causing the patient to be distracted and be less conscious of their condition.
Based on these studies, we conclude that VR can be an effective addition for alleviating pain. There are indications for a relation between the level of immersion and distressing symptomatology. Immersive VR was found to be more effective in relieving pain than non-immersive VR [22, 13]. Hence, focusing on creating high immersive presence is essential for VR that aims to alleviate pain.

2.2 Affective content

It had been shown that affective content in a VR environment resulted in a more engaging, natural and real experience. This type of content can positively affect the immersive presence of the user compared to neutral content [1]. In a different study, they had found that in a relaxed environment, a positive correlation exists between presence and positive emotions [16]. However, this only provided information that affective content could support presence or that the environment can strengthen the relation between presence and emotion.

The aforementioned studies investigated the influence of affective content and immersive presence, and the influence of an affective environment and immersive presence. We set out to identify a relation between a specific emotion and immersive presence in VR.

2.3 Laughter

It had been shown that laughter can increase discomfort thresholds and that listening to canned (recorded) laughter can stimulate laughter within the subject itself. [6, 15]. These two effects create an interesting situation. In this research we focused on the relation between laughter and immersive presence, but subjectivation to laughter can also induce laughter in the subject itself and therefore increase discomfort levels. If a positive relation between laughter and immersive presence emerges, it creates two possible ways that can assist in a pain management context, whilst using only one stimulus. This makes laughter a compelling choice for this research.

It had been shown that differentiation of emotion in laughter is possible [21]. Professional actors were instructed to produce four different types of laughter, i.e. joy, tickling, schadenfreude, taunt, with auto-induction techniques, i.e. method acting, to enhance naturalness. This study concluded that laughter can communicate the emotion of the sender and can be differentiated by the receiver, with an overall emotional recognition rate of 44%. A seemingly low accuracy, but this can be mitigated by selecting the stimulus from the Montreal Affective Voices (MAV) corpus. This corpus has identified the emotional characteristics of their recordings. Therefore, a recording can be selected that has already been categorized into a specific emotion.

Laughter had also been identified using emotional dimensions, i.e. arousal, valence [21]. Positive laughter, i.e. joyful, is usually associated with low arousal, but joy has also been associated with high arousal [2]. The level of arousal can differ depending on the context [21]. Joy is in both cases associated with positive valence.

Laughter had been found to appear more frequently during topic transitions (the final quarter of one topic and the first quarter of the next topic) than topic continuations (the central half of each topic) during solo laughter [4]. Therefore, it would be more natural to the dynamics of a conversation to integrate laughter during these transitions.

2.4 Measuring presence

Presence can be measured by objective, i.e. behavioural or physiological, or subjective, i.e. questionnaires, measurement. Two methods were found to measure presence via behaviour in this study. First method: presence is measured based on the response of the subject regarding the location of a radio. If the VR would induce high levels of presence, the subject would not have been able to correctly give the radio’s location. Second method: presence is measured by analyzing human to human interaction in a multi-user virtual environment. Both methods had been found to successfully measure presence. However, these methods requires either interaction with physical and virtual objects or interaction with other humans.

Presence measurement via physiology had been conducted by measuring heart rate, skin temperature and skin conductivity [14, 19]. Only skin conductivity had been found to correlate highly with presence. However, the change of conductivity might be related to changes in arousal and valence and not presence [11]. Heart rate and skin temperature results were inconclusive due to noise or not allowing time for maximal skin temperature change.

Subjective presence measurements are performed by conducting questionnaires. This type of measurement is commonly used and was utilized in studies, as mentioned in 2.1, to measure immersive presence in the context of VR and/or pain management. Questionnaires, e.g. Presence Questionnaire and Igroup Presence Questionnaire, offer often richer feedback and have been tested for their internal consistency [18, 19, 23].

2.5 Factors influencing presence

Three major factors can influence presence. Vividness, the ability of a technology to produce a sensorially rich mediated environment, interactivity, the extent to which users can partake in modifying the form and content of a mediated environment in real time, and user characteristics, different individuals when being confronted with the same VR can still experience different levels of presence because of individual differences [19]. These factors have to be controlled to prevent biased results.

2.6 Design considerations

An experimental design can be between-subject (Within) and between-subject (Between) design. Similar studies, measuring presence, had used either within or between design [1, 8, 16]. Within provides the possibility to gather measurements before and after the experiment. A before and after measurement discrepancy can be attributed to the stimulus, laughter. Bias caused by user related factors can be minimized. However, subjects in this design can be susceptible to the demand effect caused by the multiple measurements. This effect can lead to subjects changing their behaviour, their answers, either consciously or not [5]. Which will result in a discrepancy between the before and after measurements, but is caused by the demand-effect and not the stimulus. This design can also cause a carry-over effect. The subject will create a reference point after the initial part of the experiment. This results in a bias caused by the order of the experiment. Switching orders for every subject can prevent this, but bias can still exists within such a design [5]. With this design, the subject can become insensitive if the non-laughter and laughter VR setups are too similar. This effect is magnified if the stimulus is not very effective.

Between design can support external validity. This design allows for single measurements of presence after experiencing VR with or without laughter, without the possibility of the demand effect and/or the carry-over effect [5]. The demand effect is not obvious because the subject experi-
ences either laughter or non-laughter VR. The subject will be unaware of what the stimulus is. However, this design does not take into account individual differences of the subjects. A subject can naturally measure lower in presence after being subjected to presence inducing VR than a subject that was subjected to presence neutral VR.

Selecting the appropriate type of design and measurement is key to answer the research question. Both designs have pros and cons, but neither seems to provide a definitive design to execute this experiment. Objective measurements can provide concrete data, but will not always be applicable in the context or deliver results, and a subjective measurement can be prone to individual differences.

3. APPROACH

In this section we present our methodology, target group, setup, pilot and analysis to answer the research question. We measured immersive presence twice, before and after, of two groups that will either experience VR with laughter or VR without laughter.

3.1 Methodology

3.1.1 Measurement

While objective measurements could produce more consistent and concrete data of how an user might experience presence, they are not applicable in this research. Pain alleviation is related to the level of immersive presence the user feels within the VR. One might ‘feel’ more immersed in the VR and indicate a decrease of pain, without a significant change in observable behaviour, as it is a matter of being conscious of your pain. Therefore it is sufficient to use a subjective measurement wherein the user measures their ‘feeling’ of immersive presence.

To measure immersive presence the Igroup Presence Questionnaire (IPQ) was utilized. The IPQ is a scale for measuring the sense of presence experienced in a virtual environment. It consists of 14 questions, selected from existing presence questionnaires, with a 7-point Likert-Type Scale Response Anchors. The IPQ had been used in previous studies to measure presence, see 2.1, and had been found to have a Cronbach’s $\alpha$ of 0.85 and 0.87 [17].

The IPQ contains three sub-scales: Spatial Presence, the sense of being physically present in the virtual environment; Involvement, measuring the attention devoted to the virtual environment and the involvement experienced; Experienced Realism, measuring the subjective experience of realism in the virtual environment. We only used the Involvement sub-scale, as each sub-scale can be regarded as independent factors [17]. This sub-scale consists of 4 questions and corresponds well with our definition of presence and the relation with pain. A Cronbach’s $\alpha$ of 0.76 had been calculated in a study conducted by Igroup [17]. This is a generally acceptable reliability.

3.1.2 Mixed design

A mixed design, combination of Within and Between, was used. This resulted in a 2x2 setup, laughter and non-laughter group with before and after measurements. This minimized the effect caused by individual differences, the demand effect was controlled by not informing the subject of the stimulus and the carry-effect effect was resolved by using different VR content for the before and after measurements.

3.2 Target group

The target group were students as they are readily accessible and are generally familiar with the concept of VR. As we used a subjective questionnaire, it was still possible that the subjects could provide different answers. The subjects could be more or less sensitive to changes in their immersive presence levels due to individual differences. To minimize individual differences further, the target group was selected based on a number of requirements: age, occupation, and nationality. Age must be in a certain range, 20-25 years old. A 18 year old might have a complete different mindset as a 50 years old. Occupation will be limited to ‘student’, as students are generally in the same phase of life and therefore have similar mindsets. Lastly the nationality was also relevant, as the IPQ was presented in English, to prevent any misunderstandings of the questions. As the IPQ does not contain very difficult questions, it is sensible to think that the average Dutch university student will have an adequate English proficiency to participate.

The acquisition of the target group went through the following channels: recruitment on the University of Twente campus, inquiries based on personal or existing relationship, third-party relationship and social media. The acquisition should not influence the research in a significant way; therefore all other types of recruitment channels were also used.

We aimed for 10 subjects per group for this experiment, for a total of 20 subjects. More subjects will result in more confidence in the results of the analysis.

3.3 Setup

3.3.1 Setting

Two groups were created to research the influence of laughter on presence. Both groups experienced identical virtual content for the before measurement, but different virtual content for the after measurement. One group received virtual content with the laughter stimulus (L-VR) and the other group received virtual content with no laughter (N-VR). The before measurement acted as a baseline to observe changes caused by the after measurement’s virtual content. This baseline measurement consisted of familiarizing with the virtual environment by looking and moving around for 3 minutes. These 3 minutes coincide with the duration of the after measurement.

We minimized the factors influencing immersive presence, as mentioned in Section 2.5. Vividness was controlled by using the same technology for every subject, HTC Vive. The quality of the virtual content remained equal for all subjects. Interactivity was controlled by removing the possibility for users to modify the virtual environment. User characteristics was controlled by specifying requirements for the subjects, as mentioned in Section 3.2.

3.3.2 Experiment

The experiment was executed with the following steps: First, the subject was asked to read and sign an informed consent in order to proceed with the experiment. This form contained key information about the details of the participation, but did not contain any information about the specifications of the stimulus, research questions or goal. Second, the HTC Vive and the headset was fitted comfortably on the subject. Third, the subject started the before measurement to establish a baseline presence measurement. 3 minutes was spend in the virtual environment. Only moving and looking around was permitted. Leaving before the 3 minutes are elapsed was not allowed. Fourth, the subject was asked to fill in the IPQ. No questions were allowed towards the subject and none would be answered from the subject. Fifth, the subject entered the
VR again. Depending on the group, this could be L-VR or N-VR. The subject was instructed to listen carefully to the avatar. Sixth, the subject was asked to fill in the IPQ again. Same rules applied as in the fourth step.

3.3.3 Stimulus
A laughter recording from the MAV corpus was used [3]. This corpus provided ratings of valence, arousal and intensity for the laughter recordings. There was the possibility for variability of the arousal level, as mentioned in 2.3. Therefore the selected recording was labeled as happiness, as MAV defines it. Joyful and happiness are interchangeable terms and both represent positive emotions. The MAV provided categorization of these recordings.

3.3.4 Content

![Image](54x492 to 285x611)

Figure 1. The virtual environment from the perspective of the subject.

The content for L-VR and N-VR was told by a storytelling avatar (SA). The SA told a neutral story. This story was clipped from The Great Gatsby audiobook. This clip was selected because it is neutrally told. Therefore, the only emotion occurred from the stimulus. The clip did not contain offensive subjects, e.g. religion, discrimination, racism, sexual preference, that might offend the subject. This minimized the subject from feeling, e.g. funny, disgusted, that might affect the results.

The responding avatar (RA) provided a reaction, the stimulus, during certain topic changes when it would be most natural and it would fit the context. This would only occur in L-VR. In N-VR, RA remained quiet during these topic changes.

The subject could not interact with the avatars, e.g. make the SA stop the storytelling. The avatars and the virtual environment had a ‘cartoonish’ appearance. A realistic avatar was more difficult to create and might introduce higher expectations from the subjects. A ‘cartoonish’ avatar was simpler to create and to modify.

3.4 Pilot
A pilot was conducted to identify unforeseen problems with the setup and other factors that might influence the results. The pilot was conducted with a student that qualified the requirements for a subject. The student was asked to provide feedback at the end of the pilot. The feedback and self-made observations were used to make adjustments to the experiment.

3.5 Analysis
Due to the mixed design, analyses were conducted on the separate results of the L-VR and N-VR groups. An analysis was also conducted on the aggregated results of both groups (AGG-VR). The AGG-VR analysis focused on the effect of the laughter condition on immersive presence compared to the non-laughter condition. This was accomplished by calculating an averaged score (the average change between the before and after results) for the laughter and the non-laughter condition. The analyses for L-VR and N-VR focused on the effect of laughter on immersive presence and non-laughter on immersive presence. This was accomplished by analyzing the before and after results per group.

First, we calculated Cronbach’s α on the Involvement sub-scale for AGG-VR, L-VR and N-VR. This gave an indication if the experiment had reliable results. A Cronbach’s α of 0.70 or higher was considered acceptable.

Second, the data from AGG-VR, L-VR and N-VR were checked for their distribution by using Q-Q plot and Shapiro-Wilk test. The Q-Q plots provided a visual approximation whether the results are normally distributed or not. The data points were compared based on its actual location and the expected line which represents a normal distribution. For Shapiro-Wilk test, if (p-value > 0.05) null hypothesis cannot be rejected and the measured results are from a normal distribution.

If the null hypothesis of Shapiro-Wilk could not be rejected, a 2-sample t-test would be conducted for AGG-VR and a paired t-test would be conducted for L-VR and N-VR. If the null hypothesis could be rejected, therefore the results were not normally distributed, Mann-Whitney U test and Wilcoxon signed-rank test would be conducted instead.

3.5.1 Hypothesis
Multiple hypotheses are formulated depending on the group. **AGG-VR. H0**: There is no significant difference between the increase of the Involvement sub-scale score in L-VR and those in N-VR groups. **HA**: There is a significant difference between the increase of the Involvement sub-scale score in L-VR and those in N-VR groups.

**L-VR. H0**: There is no significant increase between the Involvement sub-scale score of the before and after measurements of the L-VR group. **HA**: There is a significant increase between the Involvement sub-scale score of the before and after measurements of the L-VR group.

**N-VR. H0**: There is no significant increase between the Involvement sub-scale score of the before and after measurements of the N-VR group. **HA**: There is a significant increase between the Involvement sub-scale score of the before and after measurements of the N-VR group.

4. RESULTS
A Cronbach’s α of 0.76 (AGG-VR), 0.75 (L-VR), 0.76 (N-VR) has been calculated. Based on these values, the data had an acceptable level of reliability. Therefore, we could proceed with the analysis.

The Q-Q plots in Figure 2, 3 and 4 indicates that all groups were normally distributed. Additionally, we conducted Shapiro-Wilk test resulting in p-values of 0.79 (AGG-VR), 0.11 (L-VR) and 0.18 (N-VR). The null hypothesis could not be rejected in all groups. Based on these findings, 2-sample t-test and paired t-tests were conducted.

The subjects of AGG-VR (n=22) reported an averaged score (the average change between the before and after results) of 5.8 (s=6.9) for the laughter condition. The non-laughter condition reported an averaged score of 3.5 (s=5.4). Even though the laughter condition scored on average higher, it was not enough to prove its superior-
Table 1. Analysis results

<table>
<thead>
<tr>
<th></th>
<th>L-VR (n=11)**</th>
<th>N-VR (n=11)*</th>
<th>AGG-VR (n=22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>11.5 (s=4.8)</td>
<td>10.7 (s=5.1)</td>
<td>5.8 (s=6.9)</td>
</tr>
<tr>
<td>After</td>
<td>17.3 (s=4.7)</td>
<td>14.2 (s=5.6)</td>
<td>3.5 (s=5.4)</td>
</tr>
<tr>
<td>Aggregated laughter</td>
<td></td>
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<tr>
<td>Aggregated non-laughter</td>
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</table>

n=number of subjects

significance level: **(paired t-test, p < 0.01), *(paired t-test, p < 0.05)

Subjects of L-VR (n=11) reported a before score of 11.5 (s=4.8) and an after score of 17.3 (s=4.7). A significant increase of immersive presence after being subjected to the laughter condition was found, (paired t-test, p<0.01). This provided an indication that the laughter condition influenced immersive presence in VR and increased immersive presence.

Subjects of N-VR (n=11) reported a before score of 10.7 (s=5.1) and 14.2 (s=5.6). Results from the N-VR group also showed an influence on immersive presence and an increase of immersive presence. But non-laughter condition was less effective than the laughter-condition, (paired t-test, p<0.05).

The change of immersive presence could be due to the virtual content (storytelling) instead of the stimulus. As the laughter stimulus showed no significant effect on immersive presence over non-laughter in the AGG-VR situation.

To answer RQ1, the laughter condition was found to significantly influence and increase immersive presence, but it is unclear if this is due to the virtual content of stimulus.

5. DISCUSSION

Based on the results we could state that the L-VR group has found a significant increase on the Involvement subscale of the IPQ (p=0.009), but the results from the N-VR group also suggested a strong increase (p=0.031). Even though significant result was not achieved, the increase on the Involvement scale of the IPQ was high and would have been significant with α=0.05 in the paired t-test. This made us believe that the effect of the VR-content was a major factor in achieving an increase on Involvement.

During the execution of the experiment, we found that the setup did not account for ambient noise. This could have been controlled and should have been eliminated to establish a more consistent environment for every participant. Therefore, there were two participants who reported being disrupted by noise, e.g. chatter. We removed the results obtained from these participants.

The content of the VR-content can be improved to increase the effect of the stimulus and to create a more natural feeling. The used audio content might not have been appropriate with the appearance of the SA and virtual environment. Three participants have either mentioned that the voice did not match the appearance of the avatar or the story did not match the context (the combination of the voice, avatars and the virtual environment). However, one participant stated that the voice and the appearance of the avatar did match and the context felt natural. The VR-content did not include certain ‘standard’ VR features, i.e. audio point-of-origin, dynamic audio gain. These features affect the perception of audio in the VR. Including
these features could have increased the effect of the stimulus which could result in stronger results and perhaps even confirming the original hypothesis.

There are two options for future work. First, there is still work to be done on other types of emotions. Based on this research, we believe that a single emotion can influence immersive presence. Identifying other emotions, that have a positive relation with immersive presence, can enable more types of VR-content, e.g. horror-, sad-themed VR, to increase its immersive presence efficacy. This could be VR that is purposed for pain management, but also for entertainment goals. As a more immersive experience can also be more entertaining.

Second, future work can retest the AGG-VR hypothesis. There were clear factors that limited this research, see Section 5 to prove this hypothesis. If successful, VR developers that focus on pain management will have an extra tool to their disposal to enhance immersive presence in VR.

6. CONCLUSION

We found a significant increase in immersive presence, compared to their baseline, in subjects that were subjected to laughter in L-VR. Subjects in the N-VR group were found to have a weaker increase in immersive presence. Laughter might influence immersive presence in a positive manner.

We were unable to find a significant difference between the effect of laughter on immersive presence, compared to non-laughter. VR without laughter did not influence immersive presence enough compared to VR without laughter. Therefore, it was not possible to state that VR with laughter was (significantly) better than VR without laughter to increase immersive presence.

Based on these findings, we suggest that joyful laughter might have positive effects within the stated research goal. As higher immersive presence decreases perceived pain and VR content that contained joyful laughter significantly increased involvement, which is similar to immersive presence.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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**APPENDIX**

**A. IGROUP PRESENCE QUESTIONNAIRE**

**Involvement sub-scale:**

1. Q: How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?
   Anchors: extremely aware-moderately aware-not aware at all.

2. Q: I was not aware of my real environment.
   Anchors: fully disagree-fully agree.

3. Q: I still paid attention to the real environment.
   Anchors: fully disagree-fully agree.

4. Q: I was completely captivated by the virtual world.
   Anchors: fully disagree-fully agree.