Asch conformity experiment using immersive virtual reality*

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Abstract

Virtual Reality is used in fields of cognitive sciences to study participants' behavior. In such cases, existence of other digital humanoid representations in the virtual envi-

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ronment is a crucial factor. Conformity - the act of matching attitudes, beliefs, and behaviors to fit with the majority - is one of the most powerful aspects of social influence. In this study, we investigated the conformity to virtual humans in an immersive virtual environment, using two experiments. In the first experiment, we investigated whether agents have social influence on the participants by conducting the Asch conformity experiment (1951). Findings demonstrate that participants' response times were affected by the judgments of the agents in the virtual environment. In the second experiment, we used a similar method to study how the factors 'agency' and 'behavioral realism' affect social conformity. 'Agency' is the extent of users belief that the other humanoid representations represent real people. The 'behavioral realism' is the degree to which humanoid representations behave as they would do in the real world. The results of the experiment showed that conformity can be caused by virtual humans in immersive virtual environments. However, there are no significant results regarding the influence of 'agency' and 'behavioral realism' on conformity.

Keywords: asch experiment, virtual reality, conformity, behavioral realism, agents, avatars

1 Introduction

Virtual Reality (VR) has been exploited in various ways in aspects related to psychology [1] [2] and cognitive sciences [3] [4] for investigating humans' behavior. According to Wilson & Soranzo [2], VR is compelling due to the almost limitless possibilities for the creation of stimuli and this has led to the spread of VR into domains of psychology. Moreover, Blascovich et al. [5] stated that social psychologists can overcome methodological problems such as the 'experimental control-mundane realism trade-off', the 'lack of replication' and 'non-representative samples' by adopting immersive virtual environment technologies as a research tool.

Exploitation of VR in psychology assumes that a human being perceives and reacts - in our case- to social cues in a virtual world as in the physical world. The existence of humanoid representations in the virtual environment, apart from the participant's avatar, is common in VR studies [6] [7] [8] increasing the realism of the scene and providing information to the participant. Moreover it allows the investigation of topics related to interactions with others, that are prohibited to be conducted in the real world, due to ethical reasons. A study replicated Miligram's [9] experiment within a virtual environment. The target for shocks was a virtual human rather than a real person, administered by real-world participants. The results showed that, even though participants were aware of the fact that the individual shocked was not real, similar findings of increased anxiety and discomfort were recorded among them.

Virtual Humans (a computer-generated human representations) in VR are classified into avatars and agents depending on who directs their behavior. Avatar is a digital representation whose behaviors reflect those executed by a specific human being. On the other hand, agent is a digital representation whose behaviors are determined by a computational algorithm [10] [11]. However, this distinction is not always clear as Bailenson & Blascovich mentioned. This is due to the inability of today's technology to accurately reflect all human actions on avatars. As a result, a virtual humanoid representation is usually constitutes of a hybrid [10] of an embodied agent and an avatar. Additionally, it is up to the developer of a VR application to inform or conceal form the user whether a virtual human is an avatar or an agent.

The effectiveness of using digital humanoid representation for eliciting realistic behavior is disputed in the literature. According to the Threshold Model of Social Influence [5], an agent cannot cause social reactions to humans, unless his behavior is very realistic [12]. The elicitation of social influence in a virtual world depends on two factors, 'agency' and 'behavioral realism'. 'Agency' is defined as the extent of user's belief that the other humanoid representations represent real people. The 'behavioral realism' is the degree to which humanoid representations behave as they would do in the real world.

Several studies have been conducted to investigate how participants' behavior change whether avatars or agents are used. The results of a study by Guadagno et al. [13] show differences in the social evaluation of participants for a 'peer counselor' with 'low agency' (agent) as compared to those with 'high agency' (avatar). In a study of Hoyt, Blascovich and Swinth [14], participants had decreased task-performance (effect of social inhibition) in a non-trained task in the presence of an avatar as compared to an agent.

Nevertheless, in other studies, ‘agency’ did not affect social behavior. For instance, a study by von der Putten et al. [11] evaluates ‘agency’ and ‘behavioral realism’, and the impact that they have on the appearance of social effects. The results showed that whether the participant believed that he interacted with an avatar or an agent, his social behavior was not affected. However, the level of ‘behavioral realism’ affects participants’ social behavior. This finding supports the theory that people unconsciously and mindlessly respond to a computer as if it were a real person [15], since the computer presents characteristics associated with humans. Revising this theory, von der Putten et al. [11] assumed that the eliciting of social reactions towards a virtual human is not affected by ‘agency’, but on the number of social cues (‘behavioral realism’).

As shown above there are several examples in the literature aiming to compare the usage of agents vs avatars with many studies proving that avatars affect social behavior of participants in a greater extent than agents, while others demonstrated no significant difference between the two. However, the use of avatars (humanoid representations controlled by real people) have a major drawback; the human resources needed to conduct a study, that is the more experimenters needed to participate in the study for controlling the digital human representations. An interesting aspect that needs more investigation is whether the existence of virtual humans can affect the participants behavior. It is also important to investigate the effect of ‘behavioral realism’ on this influence. In this study we aim to investigate these, by replicating in a virtual reality setup the well known, in psychology, Asch experiment.

Conformity

The Asch conformity experiment is among the most well-known psychology experiments [16] [17]. Conformity, one of the most powerful aspects of social influence [18], is the act of matching attitudes, beliefs, and behaviors to group norms. Norms are implicit, unsaid rules which are shared by a group of individuals and which guide their interactions with others.

In the original study, Solomon Asch [17] conducted an experiment to investigate the extent to which social pressure of the majority can influence an individual and make him/her conform. Participants were placed in a room along with seven confederates and were asked to answer some simple line length comparison test. The confederates' responses had been agreed in advance. The real participant was led to believe that the other six were real participants as well and not part of the experiment's scenario. Results, demonstrated that the participants were affected by the pressure of the majority of others. Approximately, one-third of all estimates in the critical group were distorted in the direction of the majority.

Depending on the reasons that people conform to the majority's opinion, even if it is incorrect, social conformity can be distinguished in two types, normative and informational [19]. Normative conformity occurs when the person changes his attitude or behavior to avoid rejection, to be liked or accepted by the group. In such cases, the person maintains his opinion privately. For example, in a variation of Asch's experiment, the conformity frequency was reduced when the participants had to write down their responses privately [20]. On the contrary, when the individual accepts the majority's opinion as a fact, then informational conformity occurs. In these cases, the individual complies more easily when the situation is ambiguous (e.g. greater compliance to a harder task than to an easier one [21]) or when the person feels that others have better knowledge.

Conformity to virtual humans

Recent studies have investigated the existence of social conformity to artificial agents. The first study [22] used a similar method to the Asch experiment to investigate whether non-human agents can cause social conformity. The results of the study showed no differences in the degree of conformity by an agent presented as a human, a robot, or a computer. On the contrary, the difficulty of the task (the duration for which the stimuli were presented on the screen) significantly affected the degree of compliance.

A second study [23] using Asch's example showed that participants complied with a majority of people, something that did not happen when the majority consisted of virtual agents (projected on computer screens) or computers, on easy tasks. Compliance only occurred when the task difficulty increased, by showing the stimulus for a limited duration.

Another study replicates the Asch experiment in Second Life [24], a virtual world application that enables users to create virtual representations of themselves and interact with other users. Participants were given a series of perceptual judgment trials in which they chose one out of three stimuli that matched the length of a target stimulus. Participants were tested either alone or with three other confederate human avatars whose choices were predetermined by the experimenter. In two of the trials, before the actual participants made their choice, confederate avatars unanimously chose the incorrect answer. Results showed that the participants were significantly more likely to make the same choices as the confederates, compared to participants tested as single avatars.

Aim of the study

In our study, we conducted two experiments, using a similar procedure to the Asch original experiment in order to examine the effect of social pressure from virtual humans within an immersive virtual environment. The first experiment (Experiment 1) was designed to investigate the extent to which social pressure from a group of agents could make a person to conform in an immersive virtual environment. The second experiment (Experiment 2) examined the effect of 'agency' and 'behavioral realism' on social conformity from virtual humans in an immersive virtual environment.

This study differs from [24], [23] and [22], as the participants were immersed in the virtual environment with the use of VR technology. The participants' isolation from the physical world combined with the stereoscopic projection and head tracking, strengthens presence; i.e. the feeling of being in that virtual place. We speculated that this feeling would positively contribute to social influence towards the participant.

Moreover, our study focuses on informational conformity. In our experiments, the stimuli card remains visible for participants, during the response period, making the task easier than in Rayburn-Reeves et al. study [24], where the stimuli is visible for only three seconds. The task's difficulty is a factor affecting the results of social pressure [21] and is related with the type of conformity (normative or informational).

Experiment 1

Experimental Design

We designed a VR version of the Asch experiment with a between group experimental design. Each participant was assigned either to the control group, in which case the participant's avatar was in the virtual room alone (Figure 1, top), or to the experimental group where the participant's avatar was in the virtual room with five agents (Figure 1, bottom). The participant observed the virtual environment from a first person perspective of his/her avatar. Each participant experienced one session of the Asch experiment with 12 trials in total per session (Figure 2). Each trial was a simple visual test with lines' length comparison. The trial cards with the lines appear in two boards in the virtual environment.

In the experimental group, the participant and the five agents were answering in turn to all trials. The Participants' avatar sat at in the end of the row, thus his/her turn came after he/she had heard the answers of the five confederates-agents. The five agents gave a wrong answer on 8 out of the 12 trials while in the rest, they gave the correct answer (Table 1). The visual test of each trial is predefined and the trials appeared in the same order in all sessions. The answers of the agents were also predefined and unanimous.

A label with a number on it was placed in front of each participant (participant's and agents' digital humanoid representations) in order to make clear to the participant when it was his turn to give an answer. The numbers on the labels indicated the order in which the participants of the Ash test (i.e. the participant of the experiment and agents) should give their answer. To make the order even more clear, a lamp was placed in front of all six avatars and it was lit when they had to give their answer.

Human Representations

The five confederates was represented by human-like agents, two male and three female. Each agent has two animation clips. The first clip was played repeatedly. It included small movements that gave a feeling of liveliness to the characters. The second animation clip was playing while the agent gave his/her answers. The voices used for the agents had been previously recorded by three women and two men.

The user-avatar was selected in advance by the experimenter for each session, between a male and a female character, depending on the gender of the participant. User-avatar was not animated. However, the movement of the participant's head was tracked by the tracker integrated in the HMD device, and it was mapped to the virtual camera.The camera was in a position so that the participant could see through the eyes of the avatar. In this way the participant, by moving his/her head around could observe and explore the environment, his/her virtual body and the virtual confederates.

In the control condition, the setup, the process and the trials were identical to the experimental condition besides the fact that there were no agents in the virtual room. The participants' answers as well as the time it took them to respond in each trial, were recorded in both groups.

Technical Setup

The experiment was performed using a PC equipped with an NVidia GeForce GTX 770 graphics card. The setup includes Oculus Rift DK2 head mounted display (HMD) for 3D immersive viewing and head tracking. The application was created using Unity 3D game engine and the environment using Autodesk Maya and Adobe Photoshop. The virtual characters were designed and rigged using Autodesk Character Generator.

Procedure

After being informed about the experiment, the participants signed a consent form. After that, they completed a pre-test questionnaire with demographics, virtual environments/computer games literacy and if they suffered from a vision problem. Then, they were given written instructions concerning the process. After the HMD and the headphones were fitted on each participant (Figure 3), the experimenter started the application.

The participant observed the virtual environment from a first person perspective of his avatar while sitting in front of a desk in a virtual classroom. In the case of the experimental group, the participant's avatar was sitting next to the five agents (confederates) while in the case of the control group, no other avatar besides the participant's avatar was in the room. Thanks to the Oculus Rift head tracking functionality, participants had one minute to explore visually the environment, the virtual room, their avatars' body and the avatars of the agents; the latter only in the case of the experimental group.

After the familiarization phase elapsed, the first trial appeared on the boards and the agents began to respond in turn. Agents were programmed to answer three seconds after the previous agent completed his answer. The participants had no evidence about whether the confederates are controlled by real people or not. Once the real participant stated his estimate for the visual test of the current trial, the researcher noted his answer and the process continued with the next trial. Agents responded correctly in four of the trials (trial 1, 2, 4, 11). In the remaining eight trials their answers were wrong (Table 1).

After the completion of all trials, the HMD and the headphones were removed from the participant who were asked to complete a post-test questionnaire. The questionnaire included twelve 5-point Likert style questions related to their subjective experience of immersion within the virtual environment, ownership over the avatar, 'agency' and the confidence with which they replied to the visual tests (Table 2).

Data Collection

The experimental data consisted of the participants' answers in each trial which were recorded by the experimenter, the 'response time' for each trial and the pre- and post-test questionnaires. The 'response time' is the time elapsed from the time participants' turn came, indicated by the light of the virtual lamp in front of his virtual avatar, until the real participant was gave his answer. The system was programmed to automatically record the Response Time for all cases in a text file.

Participants

22 participants between 20 and 42 years old volunteered and took part in the experiment; 14 were male and 8 female. The median age was 24 years. 13 of the 22 participants were placed in the experimental group (7 females, 6 males). The other 9 participants were placed in the control group (7 females, 2 males).

The analysis was mainly concerned the experimental group and the interaction of participants with agents while the control group data were used to validate the results. Thus, it was considered appropriate to place more participants from the available sample in the experimental group, as in the original study [16]. This allocation was taken into account during the statistical analysis and the results was not affected.

An important prerequisite was that participants should not have been familiar with the Asch experiment. As a result, 2 participants were not included in the sample.

Results

Questionnaires

Questionnaires were used to assess the participants' feeling of owning the avatar body, their sense of immersion within the scene and their confidence while answering to the visual tests/trials. These were measured on a Likert scale with values of 1 representing the highest level of disagreement at each question and 5 representing the highest level of agreement.

More than 80% answered that they used a VR technology at least once in the past. We suppose that this high percentage is because of the fact that most of the participants were students from our academic department.

The sense of body ownership, as assessed in questions 4 and 12 was quite high. The answers to these questions were grouped together after a reliability test (Cronabach's Alpha = 0.856) was performed in order to prove that the two questions measure the same construct. In the reliability test and the body ownership assessment, the answers of question 12 were reversed due to the negative way the question is stated. The median score, for the body ownership, as an average in both groups, was 3.5 out of 5. The feeling of immersion, as measured in the post-questionnaire based on the answers of the question 3, was high with a median score of 4 and minimum recorded value 3. In addition, participants in both groups stated that the process and instructions of the test were fully understood. The median scores of the relevant questions (question 1 - reverse answers and question 2) were in both cases 5.

Participants declared that they were confident for their estimates for the visual tests.

This was assessed with the post-questionnaire (questions 6, 8 - reversed answers and 11; Chronbach's Alpha = .576). More than 45% were absolutely confident while the lowest score was 3.67 on a scale from 1 to 5. The median score was 3.66.

None of the participants of the experimental condition replied absolutely positive in the question if he had the feeling that the other human representations in the virtual world were real people (question 5). On a scale from 1 to 5, the maximum score was 4 while the median was 3. This implies that the participants' sense of the virtual confederates' 'agency' was medium.

Confidence and Response Time

A Pearson product-moment correlation coefficient was computed to assess the relationship between the participants' confidence, as declared by them at question 11 of the post-questionnaire, and their Response Time in all trials of both groups. There was a negative correlation between the two variables, $r = -.475$, $n = 22$, $p = .025$. The more confident the participant felt, the more rapidly he/she gave an answer in the trials. No significant difference was found between the Confidence of the participants in the control group and the Confidence of the participants in the experimental group (mean difference = .0855, $p = .975$).

Participants' Answers

By analyzing the data, results demonstrated no significant distortion on participants' answers. 90.91% of the participants responded correctly to all questions. In a total of 264 trials in both groups, only 3 were given a wrong answer (1.14%).

Participants' Response Time

As a next step, we would like to examine whether the participants' average Response Time is affected by the responses of agents in the experimental group. A t-test was performed in order to compare means of the average Response Time of participants in the trials in which agents gave a wrong answer (M = .94, SD = 152) with the average Response Time in those trials in which agents gave a correct answer (M = 1.053, SD = .199). The results demonstrated no statistically significant difference between the two, $t(10) = -.950$, $p = .364$.

By plotting the average Response Times of participants in each trial (Figure 4), we observed a pattern in the experimental group while this was not happening in the control group. In Figure 4, the trials in which the agents in the experimental condition gave a correct answer are marked with a green line, while the red lines mark the incorrect answers. Our observations, (blue rectangles on the Figure 4 - middle), were indicating that whenever a trial in which confederates responded with an incorrect answer (red line) was followed by a trial where the confederated responded with a correct answer (green line), the average Response Time of the participants, increased drastically. Moreover, these observations were not valid in the corresponding trials in the control group (Figure 4, top).

To investigate further this, we created the ordinal variable ‘Change of Agents’ Error’ which is directly computed from ‘Agents’ Error’ variable. The ‘Agents’ Error’ is a variable that takes the value 0 in the trials in which the agents answered correctly (trials 1, 2, 4, 11), and 1 in the trials that answers of the agents were wrong (trials 3, 5, 6, 7, 8, 9, 10, 12). The ‘Change of Agents’ Error’ describes the variation of ‘Agents’ Error’ in each trial.

When the ‘Agents’ Error’ value is not changed as compared to its value for the previous trial, the value of ‘Change of Agents’ Error’ is computed to 0. In the trials in which the ‘Agents’ Error’ is 1 (agents answered wrong) while in the previous trial was 0 (agents answered correctly), the value of the ‘Change of Agents’ Error’ is 1. In the same manner, in trials in which the ‘Agents’ Error’ is 0, while in the previous trial was 1, the value of ‘Change of Agents’ Error’ is -1.

The ‘Change of Agents’ Error’ is an ordinal variable since it indicates the agent’s consistency, towards answering correctly. The ‘Change of Agents’ Error’, as computed based on ‘Agents’ Error’ of two consequent answers, is plotted in the graph of Figure 4 (bottom). The ‘Change of Agents’ Error’ for the first trial cannot be computed as there is no previous trial. Thus this value is handled as a missing one in the analysis that follows.

The similarity of the two graphs, plotting the ‘Participants’ Average Response Time’ (Figure 4, middle) and ‘Change of Agents’ Error’ (Figure 4, bottom) for each trial, can be easily observed. In order to prove it, the appropriate statistical analysis was performed. A Pearson product-moment correlation coefficient was computed to assess the relationship between the two variables; ‘Participants’ Average Response Time’ and ‘Change of Agents’ Error’. There was a high significant correlation between the two variables in experimental group, $r = .903$, $n = 11$, $p < .001$. This proves that the greater the value of ‘Change of Agents’ Error’, the more the time needed for the participants to respond.

In order to verify that this was due to the existence of agents and their answers, a similar test, a Pearson product-moment correlation coefficient between ‘Participants’ Average Response Time’ and ‘Change of Agents’ Error’ was also performed for the control group. The results for the control group, demonstrating no significant correlation ($r = .092$, $p = .789$).

Moreover, to double check that the significant correlation observed in the experimental group was due to the social influence from the agents and not due to other external factors (e.g. difference on difficulty of the visual test of each trial), we also performed a partial correlation. We controlled the ‘Participants’ Average Response Time in the control group’, in the relation between ‘Change of Agents’ Error’ and the ‘Participants’ Average Response Time’ in the experimental group. The results are demonstrated a partial correlation of $r=.904$, $p<.001$. This proves that the correlation between the two variables (‘Change of Agents’ Error’, ‘Participants’ Average Response Time’) in the experimental group, is significant, even if the values of the variable ‘Participants’ Average Response Time in the control group’ is kept constant.

Discussion on Experiment 1

This experiment was designed to investigate whether agents within virtual environments may push social pressure to the participant and influence his/her judgment.

The correct answers, as in the original Asch experiment, were deliberately obvious and undeniable, so the possible distortion on the participants' responses would constitute an extreme form of social compliance. Based on the level of 'agency' that was observed which was not very high, and the Threshold Model of Social Influence [5], we speculated that the level of social pressure which the participants received would not be high enough to make them displace their answers. This hypothesis was confirmed by our results. Participants were not replied according to the responses of the majority of agents.

Although the correctness of the participants' answers were not affected by the virtual agents, the time it took them to respond to the trials has been affected. In the trials in which the agents gave the wrong answer, whereas in the previous test were answered correctly ('Change of Agents' Error' = 1), the 'Participants' Average Response Time' was increasing significantly. The reverse is also observed. In the trials in which the agents were giving a correct answer, while in the previous trial had answered wrong ('Change of Agents' Error' = -1), the 'Participants' Average Response Time' was decreasing significantly.

This could be interpreted as a momentary force on the participants' answers, affected by the reliability of the agents and their consistency in providing correct or wrong answers. When the agents appear not to be reliable, that is in consequent trials replied in a different manner (i.e. in one trial with a correct answer and in the other with a wrong answer or vice versa), a big variation in participants' response time, is observed between times of consequent trials. If the agents brake the reliability (previous answer was correct and the current answer is wrong) then the response time of the participants increases drastically. Moreover, if the agents are recovering the reliability (previous answer was wrong and the current answer is correct), the response time of the participants decreases drastically. However, if the agents are consistent in the manner they give an answer to consequent trials, that is either they give continuously correct answers or they give continuously wrong answers, the response time of the participants does not change significantly.

Although the results of this experiment showed that it exerted some degree of social pressure on the participants, this pressure did not lead to compliance with the majority's opinion, as in the Asch's original study. This results led us to conduct a second experiment in order to further investigate the social pressure from virtual humans within immersive virtual environments. According to the literature, an important factor for social influence is the extent to which the user believes that interacting with an avatar instead of an agent ('agency'). In our first experiment we recorded the stated 'agency' using the questionnaire. In experiment 2 we tested the factor 'agency' by having an avatar and an agent group. Another factor that we examined in Experiment 2 is the 'behavioral realism' of the agents. Behaviors such as gaze direction [25] and the reactions to participant's actions are important social cues and we are expecting that they will have a great impact on social influence. We tested this factor by having an 'low behavioral realism' and a 'high behavioral realism' group.

Experiment 2

Experimental Design

The purpose of the second experiment (Experiment 2) was to examine whether the factors of ‘agency’ and ‘behavioral realism’ of virtual humans, affect social pressure. To do so, we designed an experiment with two 2 (control) x 2 (agency) x 2 (behavioral realism) between groups design. Each participant was asked to respond to a series of 12 trials, after he first heard the answers of the four confederates. The 12 trials were the same as those used in experiment 1 and are shown in Figure 2.

Control

The control condition was different from Experiment 1. Participants weren’t alone in the virtual room, but the confederates were present as well. The only difference between the control and the experimental condition was that in the control group, the confederates were giving always the correct answer. This change was done for two reasons. Firstly, to allow direct comparison of the response times between the control group and the experimental group. The second reason was to examine whether the responses of the agents which were more reliable, would affect their evaluation by the participants. In the experimental condition the confederates gave the same wrong answers as in the experimental group of

Experiment 1 and are shown in table 1.

Agency

In order to test the factor ‘agency’, each participant was randomly assigned in the ‘agent’ or in the ‘avatar group’. Even though all the confederates were agents, as their behavior was predetermined, we differentiated the ‘agency’ factor by changing the prerecorded instructions given to the participants before the study started. More specifically, in the ‘agent group’, the instructions were saying that the confederates were controlled by a computer through an algorithm. In the ‘avatar group’, the instructions were saying that the confederates were controlled by people in other labs in real time.

Behavioral realism

We created two levels of ‘behavioral realism’. Each participant was randomly assigned either in the ‘low behavioral realism’ or in the ‘high behavioral realism’ condition. The difference of the two conditions was the direction of the eye gaze of the virtual confederates. In the ‘high behavioral realism’ condition, the virtual confederates were looking straight in the eye the person who was answering, including the participant (Figure 5, top). This was done by turning both the head and the eyes of the confederates. In the ‘low behavioral realism’ condition, they were looking at the board of the trial, and the rest of the time they were looking ahead without focusing anywhere (Figure 5, bottom).

Human Representations

For this study, four human-like confederates were created, two men and two women. Each one of them had a looped animation that included small movements. A lip synchronization algorithm was also added for the movement of the lips and for eye blinking. The head movement was done with the use of code and inverse kinematics. Eye movements were also scripted. For the lip movements and eye blinking we used blend shapes animations.

Technical Setup

The experiment was performed using a PC equipped with an NVidia GeForce GTX 1060 graphics card. The setup included the Oculus Rift CV HMD for 3D immersive viewing, head rotational and positional tracking and providing the audio. The graphics and the application were created in the same way as in Experiment 1. For the lip synchronization feature, the salsa plug-in for Unity was used.

Procedure

After being informed about the experiment, the participants signed a consent form and they completed a pre-test questionnaire. After the HMD was fitted on each participant the experimenter started the application. In the beginning of the application, there was a 2.5 minute familiarization period. During this period, the prerecorded instructions were played which had a duration of one minute. The instructions included the differentiation between agent and avatar. In the avatar group participants were told that the confederates were controlled by people in other labs in real time. The participants of the agent group, were told that the confederates were controlled by a computer through an algorithm. After the familiarization period, the trial procedure started as well as the Experiment 1. After the completion of all trials, the HMD was removed from the participant who was asked to complete a post-test questionnaire.

Data Collection

The experimental data that was collected was similar with the experiment 1. They consisted of the participants' answers in each trial which were recorded by the experimenter, the 'response time' for each trial and the pre-test and post-test questionnaires. The pre-test questionnaire was identical to the one in the first experiment. It contained six questions about demographics, virtual environments/computer games literacy and if they suffered from a vision problem. The post-test questionnaire (Table 4) included seventeen 5-point Likert style questions related to the participants subjective experience of immersion within the virtual environment, social presence, agency and the confidence and the independency with which they replied to the visual tests.

Participants

52 participants, of whom 25 were males and 27 females, took part in the experiment and were randomly assigned to the conditions. The distribution of participants in the eight conditions is shown in Table 3. The median age was 25 years, raging from 18 to 60 years. As in experiment 1, an important prerequisite was that participants should not have been familiar with the Asch experiment. As a result, four participants were excluded from the analysis.

Results

23 of the 56 (41.1%) participants had never used any Virtual Reality technology in the past while 16 participants had used VR 4 or more times.

Using the post-questionnaire (Table 4), we recorded the participants' self-confidence for their responses, their sense of presence in the virtual world, their sense of social presence as well as the extent to which they were affected by the confederates' responses..

Trial Error

48 of the 52 participants (92.3%) responded correctly to all trials. The remaining four participants gave a wrong reply to at least one trial, following the mistaken reply of the confederates. Nobody taking part in the control conditions gave an wrong reply. All the wrong responses were given to critical trials (trials where the confederates gave a wrong reply) in the experimental conditions. Table 5 shows the number of incorrect responses in

each condition.

A three-way analysis of variance was conducted on the influence of the three independent variables (Control, Agency and Behavioral Realism) on the number participants wrong replies. The control variable included two levels (control and experimental), Agency consisted of two levels (low agency, high agency) and ‘behavioral realism’ also consisted of two levels (low behavioral realism, high behavioral realism). The main effect of Control yielded an F ratio of $F(1, 48) = 4.762$, $p < .05$ indicating a significant difference between participants in control ($M = 0$, $SD = 0$) and experimental group ($M = .28$, $SD = .68$). The effects of Agency and Behavioral Realism were not statistically significant at the .05 significance level.

Response time

We then looked at the response time at the critical trials. Simple main effects analysis showed no significant effect of the three independent variables (Control, Agency and Behavioral Realism) on average response time at critical trials.

We then separately tested the participants’ average response time for each trial. A three-way analysis of variance was conducted on the influence of the three independent variables (Control, Agency and Behavioral Realism) on the average response time at trial 5 showed a main effect of Control with $F(1, 48) = 7.88$, $p < .01$. Participants in the control condition replied faster ($M = .8$, $SD = .27$) on trial 5 than participants in the experimental condition ($M = 1.22$, $SD = .37$). The same significant difference between control ($M=.99$, $SD=.17$) and experimental condition (1.29, SD = .50) showed also on trial 6 with F(1, 48)=7.58, p<.01.

Social Presence

By social presence (also called co-presence) we refer to the user's sense of being and acting with 'others' in the virtual environment [26] and was assessed using four items (questions 6 reversed, 7, 8 and 9, Chronbach's Alpha = .787) on a scale of 1-5. Participants stated they had a moderate sense of social presence with a median of 3.75.

A three-way analysis of variance was conducted on the influence of the three independent variables (Control, Agency and Behavioral Realism) on social presence. The main effect of Behavioral Realism yielded an F ratio of F(1, 48) = 5.236, p <.05 indicating a significant difference between participants in 'high behavioral realism' (M=3.16, SD=1.04) and 'low behavioral realism' conditions (M = 3.81, SD = 1.02). The effects of Control and Agency were not statistically significant. This result indicates that participants in the 'high behavioral realism' condition reported stronger social presence than participants in 'low behavioral realism' condition.

Presence

We define presence as the 'subjective sense of being in the virtual world'. For the sense of presence in the virtual world, we used 3 items (questions 3, 4 and 5 reversed) based on the Slater-Usoh-Steed questionnaire [27]. The reliability of the scale was not good (Cronbach's Alpha = .437). Participants stated they had a high sense of presence in the virtual world as the median value was 4.15 on a scale of 1-5.

Confidence and Independency

34 out of the 56 participants (60.7%) stated that they were absolutely confident about their responses to the trials. Confidence was measured using four questions (questions 10, 11 reversed, 12 reversed and 13, Cronbach's Alpha = .795) in the post-questionnaire. The confidence reported by the participants appeared to be associated with the way they responded to the trials. A Spearman's rank-order correlation was run to determine the relationship between confidence and Trial Error, r_s = -.336, n = 52, p = .015. A similar correlation also occurred between confidence and response time, r_s = -.301, n = 52, p = .03. These findings indicate that participants who were less confident gave more wrong responds and spent more time answering critical trials.

The participants stated how much they responded autonomously to the trials, using two questions (questions 14 and 15 reversed) in the post-questionnaire. We constructed a scale that shows the independence (Cronbach's Alpha = .795) of the replies. 73% of the participants (38 out of 52) said they were totally autonomous with a median of 5 on a scale of 1-5. A Spearman's rank-order correlation was run to determine the relationship between independency and average response time at the critical trials. There was a negative correlation between independency and response time, which was statistically significant, r_s = -.304, n = 52, p = .029. This result indicates that participants who declared themselves more autonomous in the trials, responded more rapidly.

The variables independence and self-confidence also seemed to be correlated, $r_s = .511$, $n = 52$, $p < .01$. Participants who declared more confidence also said they were more independent in their responses.

Discussion on Experiment 2

The purpose of Experiment 2 was to study the existence of social conformity to virtual humans in immersive virtual environments. We also wanted to investigate the role of 'agency' and 'behavioral realism' in provoking this phenomenon.

The results of the experiment showed that conformity can be caused by virtual humans in virtual environments, even though the stimulus is unambiguous. This result is reinforced by the fact that no wrong answer was given in the absence of social pressure, when the confederates gave the correct answers.

This result contrasts with that of Experiment 1 where no conformity was observed although the trials and the confederates' responses of the two experiments were identical. The differences between the two experiments were the equipment used, the confederates' representations, the instructions and the familiarization period. Experiment 2 used an improved HMD version as well as an upgraded technical setup with respect to Experiment 1. The human representations used as confederates in Experiment 2 were more realistic in appearance than in Experiment 1. Also the confederates in Experiment 2 were moving their lips as they spoke, as well as their eyes, something that made them more realistic. The familiarization period prior to testing began differed between the two experiments. In Experiment 2 it lasted 150 seconds while in Experiment 1 it lasted 60 seconds. In addition, the instructions for the study in Experiment 1 were given on paper to the participants before wearing the equipment. In contrast, in Experiment 2, the participants were listening to prerecorded instructions, as ‘they were’ in the virtual world.

Also important is the fact that the wrong answers were given in the first critical trials, while no wrong answer was given to the last three critical trials. In particular, the conformity was mainly observed (4 out of 7 wrong answers) in the second and third critical tests (trials 5 and 6). In these two trials, a significant effect of social pressure (control) on response time was also observed.

The study did not produce significant results in relation to the impact of ‘agency’ and ‘behavioral realism’ on compliance. Although the ‘behavioral realism’ factor significantly affected the sense of social presence, it did not have the same impact on participants’ responses. The factor agent had no impact on the sense of social presence. Participants who were informed that the confederates were being controlled by other participants stated the same degree of social presence as those who were informed that the confederates were controlled by the computer through an algorithm.

Conclusions and Future Work

In this study it was shown that social pressure may have an impact on user behavior in immersive virtual environments that may cause conformity. This creates the need for a further study on the phenomenon of social conformity in such environments as to the factors that determine it. These factors can be divided into two categories. The first category consists of factors that influence the degree of conformity in the real world, such as the group size, the stimulus difficulty and the individual characteristics. It is possible that these factors will not affect conformity in the same way by virtual people in immersive environments as in the real world. There is also a need to study the influence of factors arising from the use of virtual reality technologies. This second category includes 'Agency' and 'Behavioral Realism' investigated in this study.

An important factor that wasn't taken into account in this study is the anonymity of the participants. Studies have shown that the conformity rate is noticeably reduced when the responses were private. In our study, although the participants gave their answers verbally, they were represented by avatars, who did not have any characteristics of their true identity. This implies some degree of anonymity that may have affected the conformity rate. This can change if the participants declared their identity to the confederates before the trials and/or if the avatars were realistic representations of the participants.

Another factor that may affect conformity is the sense of embodiment into the virtual body/avatar. The sense of embodiment is the perception of the virtual body by the participant as his biological body. This could be achieved by using real-time full body motion tracking technology and mapping the participant's movements to those of his virtual avatar. We assume that strengthening this illusion will eliminate the distinction between the self and the avatar, making participant the direct recipient of social pressure and thus affecting the rate of conformity. This speculation will be the subject of a future study.

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Figure 1: The virtual environment in the control group (top) and in the experimental group (bottom) in Experiment 1.

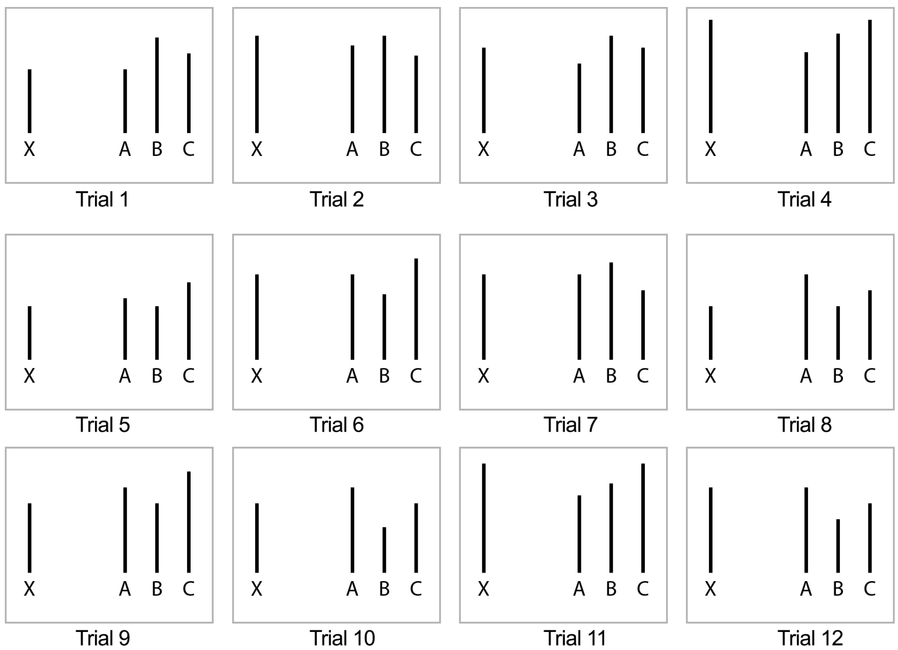

Figure 2: Each participant took part in a session with 12 trials of visual tests.

Figure 3: Participants in Experiment 1 were fitted with an HMD device for stereo display and head tracking and headphones for stereo sound.

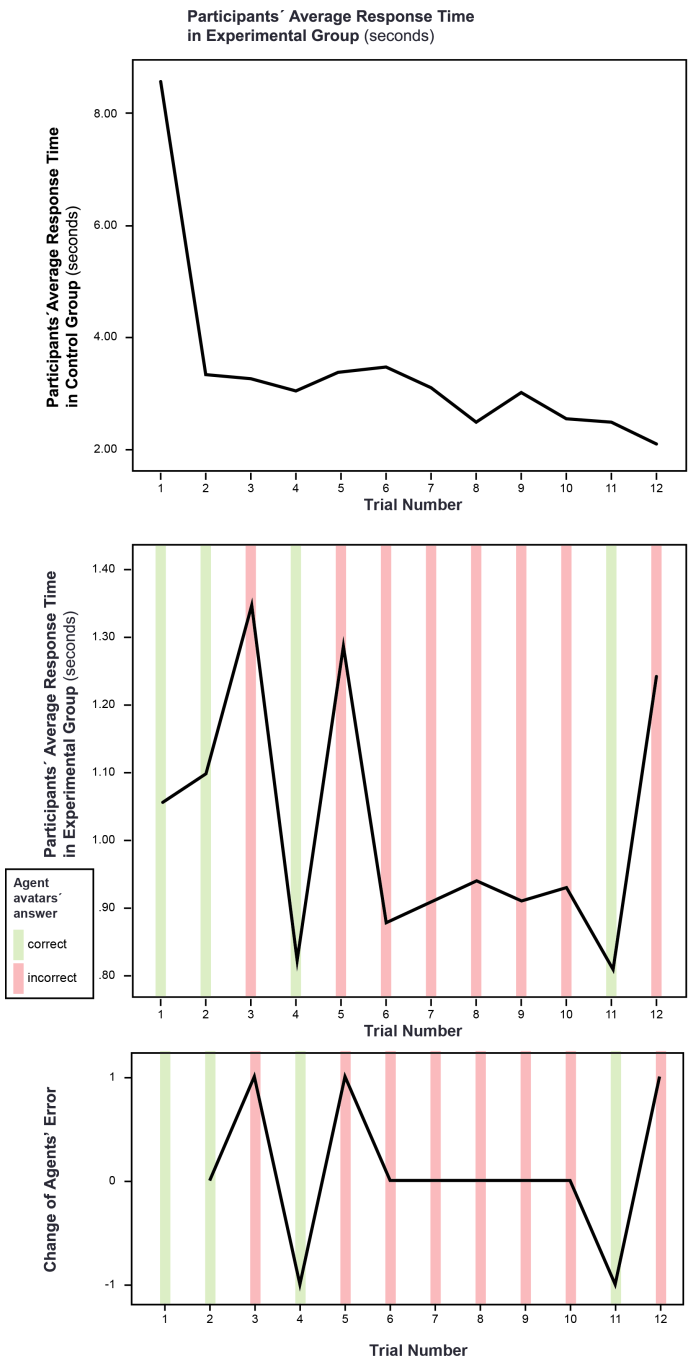

Figure 4: Participants' Average Response Time in each trial for the control group (top) and the experimental group (middle) with the corresponding 'Change of Agents' Error' in each trial in Experiment 1.

Figure 5: The virtual environment in the 'high behavioral realism' condition (top) and in the 'low behavioral realism' (bottom) in Experiment 2.

Trial Number	Correct Answer	Agents' Answer
1	A	A
2	B	B
3*	C	A
4	C	C
5*	B	C
6*	A	B
7*	A	B
8*	B	C
9*	B	A
10*	C	B
11	C	C
12*	A	C

*Critical Trials

Table 1: Visual tests' trial number with the correct answers and the answers given by agents.

	Question
1	The instructions of the study were not clear.
2	The study process was understood.
3	I felt that I was in the place / environment that I saw.
4	I felt that the body I saw when I looked down it was mine.
5*	I had the feeling that the other participants in the test were real people.
6	The answers I gave in the test were correct.
7	The trials were difficult.
8	I have doubts about the correctness of the answers I gave.
9*	The answers given by the other participants (confederates) affected my own answers.
10*	The answers I gave were mainly based on my own opinion.
11	I felt confident about my answers.
12	The body I saw when I looked down, I belonged to someone else.

*Questions given only to participants in the experimental group.

The questionnaire was in participants' native language (Greek)

Table 2: The questions of the post-test questionnaire in Experiment 1.

		Control		Experimental	
		Male	Female	Male	Female
High Behavioral Realism	Agent	3	4	5	2
	Avatar	3	4	3	3
Low Behavioral Realism	Agent	3	4	3	3
	Avatar	2	4	3	3

Table 3: Distribution of participants over conditions in Experiment 2

	Question
1	The instructions of the study were clear.
2	The study process was understood.
3	Evaluate your sense of presence in the virtual room.
4	To what extent, during your experience, the virtual world has become the ”reality” for you, and you have almost forgotten the real world in which the study was conducted?
5	During your experience, what feeling was stronger, the feeling that you were in the virtual room, or the feeling that you were in the real world?
6	I had the feeling that the body I was seeing when I looked down was mine.
7	I had the feeling that there were other people in the room.
8	I had the feeling that the other participants understood my presence in the room.
9	I had the feeling that the other participants were real people.
10	The answers I gave to the tests were correct.
11	The tests were difficult.
12	I have doubts about the correctness of the answers I gave to the tests.
13	I felt confident about my answers.
14	The answers I gave to the examination were mainly based on my own opinion.
15	The answers given by the others to the tests affected my own answers.
The questionnaire was in participants’ native language (Greek)	

Table 4: The questions of the post-test questionnaire in Experiment 2.

		Control	Experimental
Eye Contact	Agent	0	0
	Avatar	0	2
No Eye Contact	Agent	0	1
	Avatar	0	4

Table 5: Total Wrong Replies over conditions in Experiment 2