Social Presence in Two- and Three-dimensional Videoconferencing

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Abstract

New three-dimensional videoconferencing systems are trying to overcome the artificial nature of two-dimensional desktop video conferencing. The phenomenon of Social Presence serves as a measure of how natural persons feel when they are connected with a distant other through a telecommunication interface. We present a study measuring the difference in Social Presence in three conditions: (1) desktop 2D videoconferencing, (2) desktop 3D videoconferencing, and (3) face-to-face communication in a real environment, each with three participants involved. We applied two Social Presence measurement scales in an experiment with 42 subjects and found that in one scale Social Presence is rated higher in 3D than 2D. Further results are discussed in the paper.

Keywords--- Social Presence, Co-Presence, Videoconferencing, Presence measurement

1. Introduction

The success of globally and locally distributed organizations heavily depends on their ability for remote collaboration. Therefore, videoconferencing (VC) technology plays an increasingly important role as it provides a rich communication environment in which a wide range of remote collaboration tasks can be successfully accomplished. The quality and the reliability of web based video conferencing tools has improved over recent years, aided by the explosion of the internet and advances in modern network technology. In order to save travel expenses and time, many organizations apply these tools on a global scale for online meetings and presentations, or simply to keep in touch.

However, compared with real face-to-face conversation, communicating through conventional videoconferencing tools is an artificial experience. This is due to the absence of eye-contact, lack of a shared social and physical context, and a limited possibility for informal communication. These mediated systems lack "media richness" and support for verbal and non-verbal communication [5].

Recently three-dimensional metaphors have been applied in videoconferencing applications in an attempt to simulate traditional face-to-face meetings. For instance, SmartMeeting [19] provides a highly realistic conference environment involving different virtual rooms with chairs, whiteboards, virtual multi-media projectors, and even an interactive chessboard. AliceStreet [1] makes use of a similar concept, although with a more minimalist virtual room design. Participants are represented here as rotating video planes sitting around a virtual table and watching each other or a shared presentation screen. Finally, in "cAR/PE!" [15] participants can even freely move within the virtual environment and are able to place and discuss 3D models on top of the virtual table. The common goal of all of these approaches is to improve the usability of remote collaboration systems by decreasing the artificial character of a remote encounter. This goal seems to be of particular importance for the acceptance of these systems, as Biocca et al. point out:

"*The assessment of satisfaction with entertainment systems and with productive performance in teleconferencing and collaborative virtual environments is based largely on the quality of the social presence they afford"*

Biocca et al., 2001

In the study we are presenting in this paper we investigate if three dimensional interfaces are indeed able to shape a more natural sense of "being together" with remote others than traditional systems by comparing a three dimensional and a two dimensional video-conferencing interface with respect to their support for Social Presence.

Our study focuses on interactions involving three participants, in contrast to comprehensive studies with two participants only (e.g. [9]). We are assuming that this will lead to a deeper discussion of mediated multi-user communication where more than two people interact, which is common in real-world situations.

Additionally, we want to examine the power of two Social Presence measurement approaches in discriminating effects between different interfaces. This question is not trivial, as traditionally, Social Presence measurement instruments are applied in cross-media comparisons such as chat versus audio or audio only versus audio-video and not cross-interface comparisons.

2. Background: Social Presence

2.1 Definitions

Mediated Social Presence describes a feeling of togetherness of remote persons that are connected through some form of telecommunication medium. Definitions of Social Presence include the sense of "being together" [8], the sense of "Being There with others" [17], or the "perceptual illusion of non-mediation" [12]. According to Lombard and Ditton this illusion of non-mediation occurs when a person fails to perceive or acknowledge the existence of a medium in his/her communication environment. Consequently, unmediated face-to-face situations are considered the gold standard in Social Presence. The degree to what extent a telecommunication medium can support a feeling of Social Presence depends on the communication channels it provides but also on additional cues that an interface affords.

Although the presented definitions of Social Presence help to understand the concept, they are too general to derive some concrete measurement instruments. Existing Social Presence measures therefore are built on more advanced conceptualizations. However, it must be pointed out that these conceptualizations have to be seen in the context with their main concerns and emphases and thereafter lead to some inconsistencies that exist under the umbrella term Social Presence.

Because of this lack of a precise scope of definition, a promising approach is the definition of the term social presence through the validation of different instruments. This will probably lead to deeper insights into the phenomenon and eventually leads to a comprehensive understanding of the underlying concepts as well as a well-founded definition.

Therefore, in the following we outline two measurement instruments together with their definition of Social Presence.

2.2 Semantic Differential measure

In the 1970s, Short et al. were the first who defined Social Presence as the "degree of salience of the other person" [18] in their book "The Social Psychology of Telecommunication". Their work was funded and motivated by organizations such as the UK post office in order to determine the relative effectiveness of different media channels for social communication. Their focus therefore is on the medium and the attitude of customers towards the medium from a market analysis point of view. They regard Social Presence as a stable subjective quality of the medium, assuming that every user of any given communications medium is in some sense aware of the degree of Social Presence it supports. This "mental set" towards the medium in turn affects the user's nature of interaction and for example the user's media selection.

In Short's approach, the preferred method for measuring Social Presence in the laboratory is the semantic differential technique [14]. Participants are asked to rate telecommunication systems on a series of seven-point, bipolar pairs such as "impersonal – personal", "cold – warm", and "insensitive – sensitive".

Media having a high degree of Social Presence are typically rated as being warm, personal, sensitive, and sociable. This approach is still the most common way of measuring Social Presence and it has been applied in many studies.

2.3 Networked Minds measure

A more recent theory of Social Presence is given by Biocca, Harms, and Gregg [2]. Their main unit of analysis is the perceived access to another intelligence. They define mediated Social Presence as "the moment-by-moment awareness of the co-presence of another sentient being accompanied by a sense of engagement with the other… As a global, moment-by-moment sense of the other, Social Presence is an outcome of cognitive stimulations (i.e. inferences) of the other's cognitive, emotional, and behavioral dispositions". Based on a comprehensive literature review, they identify "Co-Presence", "Psychological Involvement" and "Behavioral Engagement" as the theoretical dimensions of Social Presence and name their empirically determined factors (figure 1).

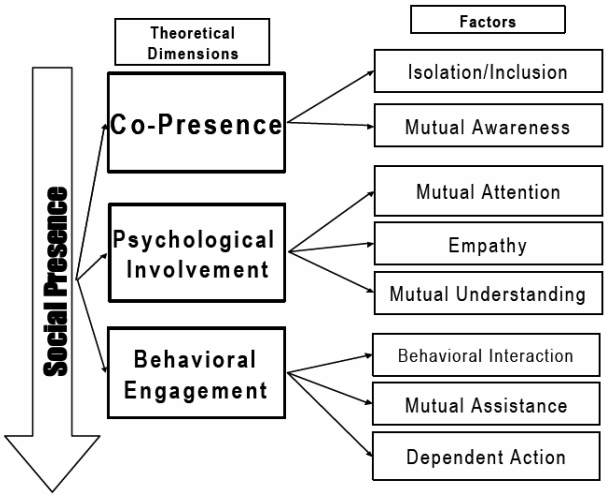

Figure 1: Factor structure of the Networked Minds measure of Social Presence [2]

Factor scale	Items	Example
Isolation/ Inclusion	2	"I often felt as if I was alone"
Mutual Awareness	4	"I hardly noticed another individual"
Mutual Attention	8	"I paid close attention to the other individual"
Empathy	6	"When I was happy, the other was happy"
Mutual Understanding	6	"The other understood what I meant"
Behavioral Interaction	6	"What I did affected what the other did"

Mutual Assistance	4	"My partner worked with me to complete the task"
Dependent Action	2	"The other could not act without me"

Table 1: Example items of the Networked Minds measure of Social Presence

The Networked Minds measure of Social Presence consists of a questionnaire which is built up by multiple items for each factor scale (see Table 1 for example items)

The important difference to Short's concept of Social Presence is, that Biocca et al. understand Social Presence rather as a varying subconscious state of a person that is linked up with a distant other than a constant property of the medium that connects them. The questionnaire items target at the experience with the remote other as the main criterion and don't assess a user's subjective judgment about how well he or she thinks the medium supports Social Presence. This approach is more in line with other conventional subjective presence measures and promises a higher sensitivity and deeper insights in different points of interest in cross-media comparisons.

3. Method

We conducted a study to investigate how a two dimensional and a three dimensional videoconferencing interface affect the sense of Social Presence. We asked participants to work on a collaborative task in groups of three in three rounds with different conditions; one condition (FTF, figure 2) where they were collocated in one room and could talk to each other face to face, and two conditions (3D, 2D, figure 3 and 4) where they were located in separate rooms, connected though either the 3D or the 2D videoconferencing interface.

Figure 2 "Face-To-Face" (FTF) Condition

After each round, every participant filled in our questionnaire on Social Presence, which we used later for our data analysis.

Figure 3 Screenshot Condition "3D"

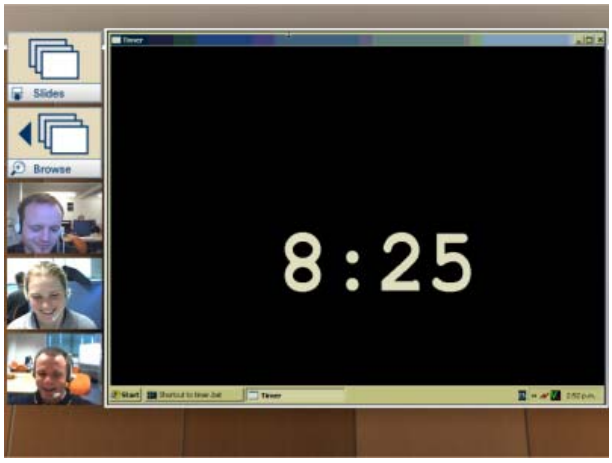

Figure 4 Screenshot Condition "2D"

3.1 Apparatus

For the mediated conditions (2D, 3D) three acoustically and visually separated rooms were prepared with identical standard desktop PC's, monitors (TFT, 17", 1280x1024), head-sets (stereo with mono microphone), and web cameras (USB, CIF resolution) (see figure 5).

All three PC's were connected using a standard 1000 MBit/sec. network, although the available bandwidth was not necessary for the application (200 KBit/sec would have been sufficient).

Both mediated conditions (2D and 3D) consisted of variants of the same videoconferencing software "cAR/PE!" as described by Regenbrecht et al. [15]. This software represents all participants as video planes in a three-dimensional virtual environment as shown in figure 3. Users can freely navigate in the virtual room while their movements are directly mapped onto the position of their video planes in the environment. Participants can thus automatically convey spatial relationships between each other: They can be virtually close or far to each other, can

face each other or the projection wall of the room, or can "sit" around a virtual table In addition the "cAR/PE!" software supports 3D-sound which further underlines the spatial character of the 3D environment.

Figure 5 Videoconferencing workplace

These features were fully available in the condition "3D". At the beginning, all participants were placed around a virtual table. Afterwards they could freely navigate within the environment using the computer mouse ("head" rotation left/right and up/down, and movement forward/backward and left/right). If a participant got "lost" in the virtual room he or she could get back to the initial position at the virtual table by clicking on a home-button shown in an interactive menu on the bottom of the screen. Integrated into the virtual environment was a virtual screen which displayed a counter with the remaining time for the current round.

In condition "2D" the subject's view into the environment was locked at a fixed position facing the timer screen (see figure 4). Video streams of the participants were shown on top of each other beside the timer screen, comparable to other conventional 2D desktop videoconferencing layouts.

In both conditions the same video and audio codecs were used (CIF resolution, 16 Bit stereo audio). The given video and audio quality was therefore constant in both mediated conditions and can thus be excluded from having any unwanted side effect. Video and audio are synchronized and the latency (loop) was about 300 msec. The size of the video for each participant in the environment in the "2D" condition was 6 cm x 4 cm measured on the monitor screen while in the "3D" condition this size varied according to the movements of the participants (own and others). In a view most participants intent to choose after a while (e.g. like in figure 3) comparable video sizes (measured on the monitor screen) as in "2D" were displayed (between 5 and 7 cm in width).

3.2 Participants

Forty-two subjects (36 male and 6 female) participated in the experiment. In 14 sessions each of three participants took part in three trials which gives a total of 126 trials. The age of the participants ranged from 19 to 63 years (median age 33 years).

Out of the 42 participants, three subjects reported to use videoconferencing tools regularly to communicate with their friends, further two subjects commonly used video-conferencing in their business context.

The participants were recruited by personal invitation mainly out of Information Science staff members. The assignment of participants to groups and time slots was based on self selection.

As an incentive a large chocolate bar was given to each participant at the end of each session.

3.3 Task

We chose the collaborative task "the Desert Survival Game" [11]. The main challenge of this task is to assign priorities to a given list of items such as a parachute, a cosmetic mirror or a compass, based on how useful the items would be for helping the group survive in a certain, given extreme situation (crash landing of an airplane in the desert). This task requires the people to work together as a team to resolve and interpret many uncertainties and to trade off all alternatives. According to the media richness theory [7], this sort of task requires a rich medium such as given in audio-video telecommunication and is thus appropriate for our experiment.

Another reason for choosing this task was the fact that the same task has been used in the pilot study of the Networked Minds measure of Social Presence [2] which we want to partly replicate and extend in our study. Choosing the same task guarantees a better comparability of results and ensures scientific stringency. In order to keep the task interesting and involving for the participants, we calculated the difference of the group's ranking with an "expert solution" after each of the three conditions to give some feedback on how well their team was doing. Based on this interim score, we then encouraged them to further improve their result in the succeeding round by reconsidering the previous ranking.

The detailed game description was found at RogerKnapp [16] and was adapted in the following ways: (1) the number of items on the ranking list was decreased to 10 (from 15 in the original task), (2) values in miles and Fahrenheit were converted to km and centigrade.

3.4 The Questionnaires

Our *Social Presence Questionnaire* was applied after each of the three trials. It consisted of a combination of both measurement instruments as described in the chapters 2.2 and 2.3.

In the first part (38 items), we used all items of the Network Minds measure of Social Presence as described in 2.3 in randomized order.

In the second part, we put 9 bipolar pairs of the semantic differential technique as described in 2.2. Similar to the approach taken by Nowak and Biocca [13] we selected items directly out of Short's Social Presence measurement instrument. The bi-polar pairs chosen are:

Impersonal	-	Personal
Cold	-	Warm
Ugly	-	Beautiful
Small	-	Large
Insensitive	-	Sensitive
Colourless	-	Colourful
Unsociable	-	Sociable
Closed	-	Open
Passive	-	Active

In addition, we applied a *General Demographics Questionnaire* once to collect some details about the participants. This questionnaire assessed gender, age, simulator experience, previous use of telecommunication tools for business and private purposes, proficiency of English, if participants had played the task (Desert Survival Game) before and if they had prior experience with the cAR\PE! system which we used.

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3.5. Procedure

The experiments were conducted during the first weeks of May 2005 at Otago University in New Zealand. For every one-hour session a group of three subjects were used. Upon arrival the participants could choose one of three seats at a table (marked as person 1, 2, 3). The participants were asked to read the *Participant Information*, explaining (1) the goal of the experiment (investigating differences in previous experiences with videoconferencing systems), (2) the general procedure, (3) the anonymity of the experiment, and (4) a participant consent text, which was to be signed by the subjects. Additionally the document contained the *General Demographics Questionnaire*.

After completion, a second sheet was handed out for reading: the *Participant Instruction,* which describes the Desert Survival Game.

Each participant had to take part in three rounds, one for each condition (FTF, 2D, 3D). The order of conditions was randomized beforehand (Latin Square). The task in each condition was the same (ranking of item list) and the group was told the interim result after each condition. One participant in each condition had the role of the "scribe", who had the list of items and who had to compile the group ranking list to be presented after each round.

In the 3D condition, the participants could navigate within the videoconferencing environment using a simple mouse interface. Participants were given an introduction of how to use this mouse interface and had then approximately 2 minutes to make themselves familiar with it. They were invited to think of the interface "as if they were together in a real room" and were encouraged to make use of the spatial cues the interface provides. A sheet explaining the mouse interface with pictures was put at the workplace as a further reference.

The 2D condition did not require any instruction. In both mediated conditions (2D, 3D), the subjects wore audio head-sets (see figure 5) which were explained and adjusted for best comfort.

After each condition, the subjects came back together and filled in the *Social Presence Questionnaire* on paper. The interim score of their ranking was announced and they continued to the next condition trying to further improve their result.

The experimenters played a passive role. They were only instructed to assist the participants in case of unforeseen circumstances or to help with the equipment. In addition, the experimenters made notes of their observations.

The last two sessions (6 trials) have been recorded on video tape for later use after agreement of the participants.

3.6. Hypotheses

We conducted three pilot test sessions (9 trials) with slightly altered setups and tasks before the actual experiment. Based on the first user reactions and the first measurement results, our general assumption was that a three-dimensional interface can support a higher sense of Social Presence than the two dimensional one, but supports less Social Presence than the Face-to-Face situation.

Regarding the first questionnaire results, the data we collected of the Networked Minds measure of Social Presence showed that not all items discriminated between the two mediated conditions but more clearly between the face to face and the mediated conditions. This lead to our experiment hypothesis number 1.

Hypotheses 1: Every factor of Social Presence, measured with the Networked Minds measure of Social Presence, is higher in the Face-To-Face condition than in both mediated conditions and at least several factor scores of Social Presence are higher with the three-dimensional interface than with the two dimensional one.

The semantic differential technique seemed to result in more uniform responses that tended to clearly discriminate between every condition. From this finding we derived hypothesis 2.

Hypothesis 2: Social Presence, measured with the semantic differential technique, is higher in the Face-To-Face condition than in both mediated conditions and Social Presence also is higher with the three-dimensional interface than with the two-dimensional one.

4. Results

The results presented in this chapter have been analyzed using SPSS version 11.

4.1 Reliability analysis

As all measured factors are multiple-item additive scales, a reliability analysis of the items in all factors was performed first. For this, Cronbach's Alpha was calculated for each variable (see tables 2 and 3).

Factor	Nr of Items	Alpha
Social Presence	9	0.93

Table 2: Test for internal consistency for the semantic differential measure of Social Presence

Factor	Nr of Items	Alpha
Isolation	2	0.54
Mutual Awareness	6	0.83
Mutual Attention	8	0.76
Empathy	6	0.70
Mutual Understanding	6	0.88
Behavioral Interaction	6	0.84
Mutual Assistance	4	0.74
Dependent Action	2	0.32

Table 3: Test for internal consistency for the Networked Minds measure of Social Presence

The alpha score for the factor Social Presence using the bi-polar pairs is very good, suggesting that the items measure a single uni-dimensional construct sufficiently well. Short identified this construct as Social Presence in his studies using the same items. The high alpha value also shows that an occasional appearing second orthogonal factor, which Short referred to as "aesthetic appeal", doesn't form in our case. Instead this factor seems to fuse with the dimension Social Presence so that all 9 items indeed describe the same dimension.

In the Networked Minds measure of Social Presence, the factors "Isolation" and "Dependent Action" reached an insufficient Alpha score and are therefore excluded from further analysis. This result of reliability is in line with the results of the pilot study presented by Biocca et al. [4].

No strong correlations were found between the different factor scores of both instruments. The strongest inter-correlation between scales of the two different measurement instruments appeared between the factor mutual understanding and the pair "cold-warm" in the 3D condition with a Pearson correlation factor of 0.58, $p<0.001$ and between mutual understanding and the pair "insensitive-sensitive" with a correlation factor of 0.63, $p<0.001$ in the 2D condition.

4.2. Comparing Means

The results of both measures are presented separately in the following two sections.

4.2.1 Networked Minds measure

The average score and standard error were calculated for every factor in the Networked Minds Measure of Social Presence and are displayed in figure 6. For a more detailed information about all sub-scores, please refer to Appendix A and B.

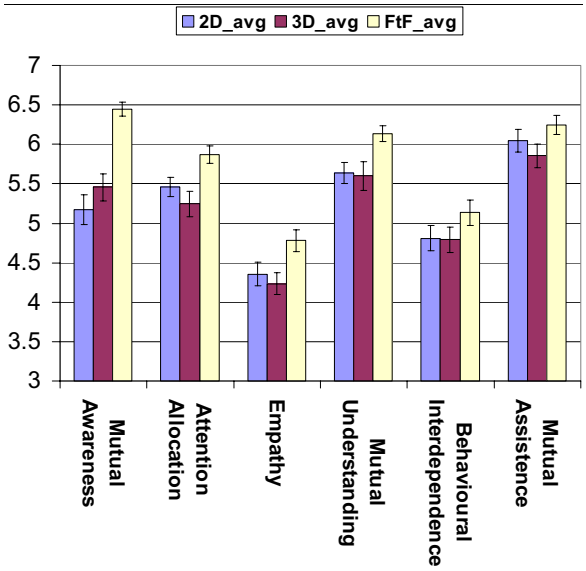

Figure 6: Mean differences and standard errors in the factors of Social Presence, as measured by the Networked Minds Measure of Social Presence

In every factor, the score of the Face-To-Face condition reached the highest value. Furthermore, every factor was analyzed in an analysis of variance with media (FTF vs. 3D vs. 2D) as a within-subject factor. The main effect of media was significant for all factors. Post-Hoc comparisons were performed using the Bonferroni adjustment for multiple comparisons. The scores of the face-to-face condition were significantly higher than the scores of the 3D condition in all factor scales. The scores for of the Face-To-Face condition was significantly higher than the 2D condition in the factors Mutual Awareness ($p<0.01$), Mutual Understanding ($p<0.01$), Attention Allocation ($p<0.05$), and Empathy ($p<0.01$). This result is slightly different from the findings of the Biocca's pilot test, which found significant differences between Face-To-Face and a 2D videoconferencing interface only in Mutual Awareness, Mutual Attention, and Mutual Assistance. No significant differences ($p<0.05$) could be found in any of the factors between the condition 3D and 2D.

H1 could therefore only be partly supported as not all factors were significantly higher in the face to face condition than in the 2D condition and there were no factors that showed any significant difference between the conditions 2D and 3D.

4.2.2 Semantic differential measure

The mean value and standard error of the dimension Social Presence as measured with the semantic differential technique, is displayed in figure 7.

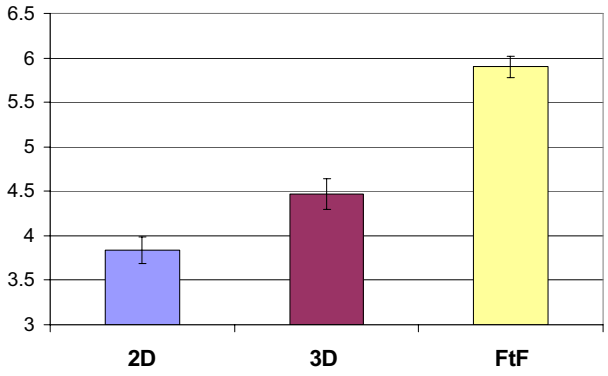

Figure 7: Mean Difference and Standard Error in Social Presence, measured with the semantic differential measure of Social Presence

The mean values of every condition were compared in an analysis of variance with media (FTF vs. 3D vs. 2D) as a within-subject factor. The main effect of media was significant for Social Presence, $F(2,82)=64.78$, $p<0.01$. After that, pair wise post-hoc comparisons were performed using the Bonferroni adjustment for multiple comparisons. The Social Presence mean score in the Face-To-Face condition ($M=5.90$, $SD=0.77$) was significantly higher than it was in the 3D condition ($M=4.47$, $SD=1.11$, $p<0.01$) and in the 2D condition ($M=3.84$, $SD=1.00$, $p<0.01$). Furthermore, the measured Social Presence in the 3D condition was significantly higher than the 2D condition ($p<0.05$).

The hypothesis H2 was thus fully supported. Social Presence, measured with the semantic differential technique is indeed higher in the Face-To-Face condition than in both mediated conditions and the three-dimensional interface can support a higher Social Presence than the two dimensional one.

5. Further Findings and Limitations

The control variables order, age, simulator experience, gender, proficiency in English, and experience with telecommunication technology were tested for further effects on all factors. No significant effects ($p<0.05$) were detected. (highest within-subject effects for Social Presence (measured with the semantic differential technique) , and gender $F(2,50)=1.99$, $p=0.15$, and Social Presence and age $F(6,50)=1.66$, $p=0.15$, both not significant.) This result shows that the semantic differential technique is quite robust against variable disturbances.

The experimenters wrote notes during the sessions about their observations. The intention for this procedure was to explore clues for further experiments in the field and to get some informal hints about the usability of the concepts tested. Although these observations lack empirical evidence, they are useful for explaining reasons behind the measures. Some of these anecdotal situations are:

While head-movement in reality is very fast and does not need any interface (except for the already learned one), its substitute in the 3D conferencing interface needs to be improved. Obviously the interface is not fast enough to meet the expectations of the participants. Turning the (virtual) head with a computer mouse is not fast and robust enough or deserves more training. For instance asking participants who frequently play computer games with their PC they would prefer a keyboard or combined keyboard/mouse interface because it is more "natural" for them.

There were clear indicators that users understood the spatial character of the interface in the 3D condition. For example, users frequently turned their avatar away from the other avatars towards the projection screen to see the timer and then back again, imitating a glimpse to the clock in a real room. Users also clearly liked and exploited the 3D sound for example, by adjusting the own avatar's view direction towards an avatar who was out of the view while talking to them.

Very often participants tried to navigate to a "comfortable view" position (two others in view). The pre-set field of view of the software system used did not allow for three participants to see each other in that kind of view, so at least one participant had only one person in view and had to do a lot more virtual head rotations when wanting to see the communication partners. This could be improved in future versions of the system by either changing the virtual field of view in the environment (with a trade-off in correct perspective view) or by altering the navigation interface.

Occasionally, the sheet with the interim rankings was held in front of the camera by the "scribe" to show it to the other participants. Obviously there is some need to present something to others even in this mainly verbal task. Therefore, the approaches taken by AliceStreet [1], SmartMeeting [19] and Regenbrecht et al. [15] to include virtual presentation mechanisms into their environments seem to be logical. From an interface design point of view and considering these observations, a more "natural" interaction metaphor should be provided for the presentation of real world objects (like documents).

The "scribe" was almost always looking down to his/her sheet and therefore was not seeking face contact with the others. The communication took place on an

almost audio-only channel. Surprisingly there was no effect on the results. This might lead to the assumption that the mediated environment was cognitively and emotionally "understood" within the first minutes of contact and later on taken for granted. So, the "scribe" was aware of the environment (and the perception of the others of it and of him/herself) even when not using the medium continuously. The three-dimensional audio capabilities of the system (to hear the other participants from their spatial position within the environment) could also have been contributing to this behavior and rating.

It was also observed that the display of the video stream of oneself in the 2D condition was valued as advantageous. It apparently gave some faith in using the system to know how others were seeing one. The same feature was present in the 3D condition (displayed video streams of all participants on the virtual room wall opposite to the presentation screen and table) but almost nobody made use of it. Perhaps it was simply too "laborious" to navigate to this place in the virtual environment.

We would also like to mention that evaluative studies of new media such as a 3D Videoconferencing system could also be distorted by a certain "Wow-Effect" by first time users. As Ijsselsteijn [10] points out in a review of the introductions of age-old media technologies, people's first responses to new and more realistic media such as the first photograph, first movie, or the first virtual environment have always been characterised as being very exciting, emotional, and intriguing. However, the reason for this is more grounded in the fact that previous expectations with and experiences of users were exceeded, rather than the sensory information that this medium provides could be improved. In our study we therefore have to be aware that this effect might also have an impact when we ask participants for their emotional attitudes of a new 3D-interface versus a common 2D one.

6. Discussion

With the presented experiment we have successfully replicated the Pilot Study of the Networked Minds measure of Social Presence in a three person setup. The results of our Networked Minds measure confirm, that the instrument is capable of discriminating the experienced Social Presence between unmediated and audio-video mediated communication. However, the instrument was not sensitive to comparisons within the two video conferencing interfaces. Also, we found the factors of *isolation* and *dependent action* failed the criteria for internal consistency. This suggests that the items in these factors should be reconsidered and modified in future studies. At this point it would also be interesting to run a factor analysis involving both our data and the Networked Minds Lab pilot study data sets to refine the current factor structure.

Using the semantic differential technique we succeeded to find a difference not only between the Face-To-Face versus the two audio-video mediated settings, but also between the two audio-video interfaces themselves in the Social Presence scale. This result confirms studies by Christie [6] where the hypothesis that the Social Presence dimension would discriminate even between variations of the same telecommunications medium was supported. The result of our semantic differential measure implies that the 3D-videoconferencing is rated to be more capable of supporting a high sense of Social Presence than the 2D version.

From an interface designer's point of view, this is a very encouraging result, suggesting that the semantic differential technique is sensitive enough to evaluate different interface features of telecommunication systems with respect to Social Presence as Short et al. defined it. For example in our presented experiment, the concept of 3D videoconferencing was encouraged as it seems that it has some positive effects on the user's attitude towards the medium. The instrument seems to be valid, elegant and robust, as it can be universally applied for different media and different tasks.

From a presence researcher's point of view, however, our result shows that in its current version, the Networked Minds questionnaire alone is not able to inform about how the experience of Social Presence is affected by telecommunication interfaces. Future evaluative studies should therefore try to add objective or physiological measurements as well.

A more robust and uniform theory and measure of the experience of Social Presence could advance many fields of telecommunications research including the exploration of design goals, properties and effects of telecommunication systems [4]. We believe that the Networked Minds theory of Social Presence is a good first step towards such a robust theory, but further efforts are required.

Having a look at the overall ratings in all factors apparently the Face-To-Face situation is still the gold standard as expected. The differences measured are clearly higher between the FTF and the mediated conditions compared to the differences between the mediated conditions (if any).

The increase in Social Presence, which we measured with the semantic differential technique, in the order 2D-3D-FTF, indicates that the more the system is similar to the FTF situation the higher the Social Presence. This leads to the assumption that an interface design towards three-dimensionality is a founded one.

We used 3-participant-groups, in contrast to many studies in social presence that involved only two interlocutors [2][9]. The result of our three person setup might give an idea, how the situation might scale to a larger number of people. Clearly, the more interlocutors are participating in a videoconference, the bigger is the need for them to stay aware of both, the situation and the others. Our result could be a first indicator that providing spatial

Video Conferencing systems which support a higher sense of Social Presence could be especially useful in multi-person scenarios.

It can reasonably be expected that a truly three-dimensional task would even further increase ones sense of Social Presence. E.g. the task described by Regenbrecht et al. [15], where the design of different 3D car models had to be evaluated, would probably benefit from the three-dimensionality of the environment itself. Further investigations are needed here to prove this assumption.

While the focus of this study was set on perceptual issues, namely Social Presence, the question remains if task performance can be increased by using three-dimensional user interfaces rather than two-dimensional ones. Empirical evidence here would clearly strengthen the argument for this new kind of environments. We assume that task performance will positively correlate with communication quality in computer-mediated communication. Further research is needed here.

7. Conclusions

We have shown that Social Presence increase from two- and three-dimensional mediated to real face-to-face communication. While the natural face-to-face meeting situation is still by far the benchmark for all mediated systems the introduction of three-dimensionality in computer-mediated communication is a well-founded step.

While the instrument given by Short et al. [18] is a reliable and elegant one to measure the main dimensions of this study, further work is needed towards a robust theory and measure regarding all other dimensions. This was stated by Biocca at al. [4] and could be reinforced here.

Based on our results, further findings, and observations in this study we believe that research and development in three-dimensional video-conferencing can be seminal.

We hope that researchers and practitioners in the field will benefit from our findings and that we can contribute with this study and in the future to more effective, efficient, and enjoyable computer-mediated communication interfaces.

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Appendix A: Descriptive statistics table for the Social Presence Items

Social Presence (sem.dif.)	FTF			3D			2D		
	mean	std. error	std. dev.	Mean	std. error	std. dev.	mean	std. Error	std. dev.
cold -warm	6.29	0.14	0.89	4.43	0.24	1.53	3.93	0.22	1.40
impersonal-personal	6.31	0.19	1.20	4.29	0.22	1.44	3.95	0.21	1.34
unsociable-sociable	6.64	0.10	0.62	4.71	0.21	1.33	4.33	0.20	1.30
closed-open	5.98	0.20	1.28	4.24	0.23	1.48	3.86	0.24	1.57
ugly-beautiful	4.88	0.15	1.00	4.31	0.22	1.41	3.67	0.18	1.16
colourless-colourful	5.33	0.23	1.48	4.64	0.21	1.34	3.71	0.24	1.55
passive-active	6.24	0.16	1.01	4.90	0.23	1.49	4.26	0.24	1.58
insensitive-sensitive	6.10	0.15	0.98	4.43	0.21	1.36	3.71	0.17	1.09
small-large	5.33	0.23	1.51	4.29	0.22	1.44	3.12	0.20	1.31

Appendix B: Descriptive statistics table for all sub factors in the Networked Minds Questionnaire

Networked Minds Measure of Social Presence factors	FTF			3D			2D		
	mean	std. error	std. dev.	mean	std. error	std. dev.	mean	std. Error	std. dev.
Mutual Awareness	6.45	0.09	0.61	5.46	0.17	1.11	5.17	0.19	1.22
Mutual Understanding	6.13	0.10	0.68	5.60	0.18	1.17	5.64	0.13	0.85
Mutual Assistance	6.24	0.11	0.76	5.86	0.16	1.05	6.05	0.12	0.77
Empathy	4.79	0.14	0.89	4.23	0.14	0.93	4.35	0.15	0.98
Attention Allocation	5.87	0.12	0.75	5.24	0.15	0.99	5.46	0.14	0.89
Beh. Interdependence	5.13	0.16	1.00	4.79	0.16	1.06	4.81	0.16	1.05