Bachelor Thesis

Finding the Preference of Interpersonal Distance in Dyads Using a Virtual Environment

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Abstract

Using a virtual environment (VE) to study interpersonal distance is a good tool to find the preferred interpersonal distance of individuals. This study used a 2 (distance: 75 cm to 300cm) x 2 (difference in perspective: Bird's-Eye View vs. Point of View) within-groups design to determine the preference of interpersonal distance. Pairwise comparison was used to decide which distances are similar and preferred and which are less preferred by the participants. The depicted distances ranged from 75cm to 300cm in 25cm increments. It was concluded that there is no difference of perception when changing the perspective. Furthermore, most people preferred smaller distances over larger distances. Both conditions demonstrated that the distances 100cm, 125cm, and 150cm were perceived as most preferred by the participants. Furthermore, the estimation analysis of distances in virtual environment showed that the distances were systematically underestimated by the factor 0.59 in the Point of View condition and 0.61 in the Bird's-Eye View condition.

Keywords: Interpersonal Distance, Virtual Environment, Feedback, Monitoring Behaviour, Dyads

Introduction

Working in teams and groups is globally established to enhance performance, outcome, and feasibility of plans but it also allows for creativity and time management. Teamwork can be carried out traditionally by working at the same place on independent or interdependent tasks or in modern ways with technologies that enhance communication when team members are geographically separated. There is a lot of research on the positive effects of well carried-out teamwork and its benefits over individual task management (Sanyal & Hisam, 2018). Sanyal and Hisam (2018) describe teamwork as a necessary step for teams to enhance their performance. Fletcher and Major (2017) introduced the four core processes that define teamwork, namely: communication, feedback, mutual performance monitoring, and backup behaviours (Fletcher & Major, 2017; McIntyre & Salas, 1995). Accordingly, these processes can predict the efficiency, productivity, and performance of teams (Fletcher & Major, 2017).

Core Processes of Teamwork

Communication. In team environments, communication is key to establish a common idea of tasks, roles, and activity plans (Fletcher & Major, 2017). However, in Command & Control (C&C) teams communication is not used for sharing unnecessary information but rather for task-oriented knowledge that enhances the ability to have a shared idea of the task. Thus, information is shared as feedback within a team to improve performance (Rasker, Post, & Schraagen, 2010).

Feedback. The above-mentioned use of communication in C&C teams, in that it is task-oriented, builds an environment that focuses on task-related information and actions. Hence, it allows individuals to engage in high-quality feedback behaviour (Rasker et al., 2010). If not everyone is sharing their information, feedback processes are inhibited (Albon & Jewels, 2014).

Mutual Performance Monitoring. Another aspect of teamwork is mutual performance monitoring which is the mutual awareness of another's workload, task, and need of help (Albon & Jewels, 2011). Rasker et al. (2010) describe performance monitoring as a function of feedback, in that it is a crucial step to give beneficial feedback. Also, the aim of performance monitoring is to know when a team member needs support (Fletcher & Major, 2017).

Backup Behaviour. When working in teams on different tasks with a high workload, providing backup behaviour is essential for the outcome to be sufficient. Backup behaviour is defined as the support of group members for them to carry out their task properly (Porter, Hollenbeck, Ilgen, Ellis, West, & Moon, 2003). Porter et al. (2003) showed that it can be predicted by the provider's and receiver's personality as well as the legitimacy of the need for backup behaviour.

Work Environment

When it comes to traditional groups working in one location, it is crucial to include these processes in the design of the team environment. Especially, mutual performance monitoring and providing backup behaviour have a significant influence on teamwork and the effectiveness of teams in general (McIntyre & Salas, 1995; Rasker et al., 2010). Therefore, it is crucial to find the perfect setting, environment, and atmosphere that enhances these processes. As mentioned earlier, the improvement of communication, feedback, monitoring, and backup behaviour leads to better performances within a group (McIntyre & Salas, 1995).

Many factors influence how team members engage in these processes and consequently the level to which they work effectively and efficiently as a team. Especially within traditional team makeups, factors of the environment play an important role. Previous research has focused on influences like room temperature and working hours (Lan, Lian, Pan, & Ye, 2009).

Hence, the ideal work environment influences the comfort and effectiveness of teamwork. However, there is little knowledge on how the interpersonal space between group members can influence teamwork behaviours and therefore the performance and effectiveness. Interpersonal space seems to be a rather vague concept in teamwork environments because it is flexible to change. However, it influences everyday behaviour in dyads, and it is important to find out what interpersonal distance is preferred by individuals, so they can carry out tasks effectively. This preference can be utilized to design work environments in which individuals feel comfortable (Sundstrom & Altman, 1976).

Interpersonal Distance

Sundstrom and Altman (1976) described interpersonal distance as a factor that can lead to 'discomfort or dissatisfaction' and therefore influences the engagement in task-related behaviour. It is the invisible space around a person that when intruded by another individual will lead to uneasiness or displeasure (Kinoe, 2018). Furthermore, Sundstrom and Altman (1976) state that individuals seek to have a satisfying distance between each other. This distance depends on sex, sexuality, gender role, posture, and situation (Kinoe & Mizuno, 2015; Uzzell & Horne, 2006). Kinoe (2018) found that when dyads engage in cooperative tasks they would shorten their interpersonal distance. He concludes that interpersonal distance can be very dynamic; in that it changes from the type of task and situation. In other words, it is important to predict the right interpersonal distance in order for teams to have a satisfying performance.

Many researchers investigated how differences in interpersonal distance change behaviour or communication (Kinoe & Mizuno, 2015; Kinoe, 2019; Russo, 1975; Uzzell & Horne, 2006). The way two individuals face each other influences how far apart they are. Kinoe (2018) found that the interpersonal distance between two persons is smaller when they are side-by-side compared to face-to-face. Another interesting point is that the larger the distance between the individuals the higher the number of times individuals engage in eye contact (Russo, 1975). This shows that interpersonal distance accounts for several behavioural changes in humans and is, therefore, a factor that should be included when designing work environments.

As mentioned earlier, interpersonal distance can be a source of discomfort or even a threat. Perry, Rubinstein, Peled, and Shamay-Tsoory (2013) showed that socially anxious people have a feeling of threat or dissatisfaction sooner than individuals who are less socially anxious. This means, these individuals will choose a larger distance to other people in order to feel better. Accordingly, they will work more efficiently in an environment that presents them with larger distances to other people. Highly empathetic individuals, on the other hand, prefer a smaller interpersonal distance (Perry, Mankuta & Shamay-Tsoory, 2014). These differences clearly show that it is crucial to determine preferences of interpersonal distance for teams in order for them to work as efficiently and comfortably as possible in their environment.

Goals of the Present Work

In order to find a comfortable interpersonal distance, we want to investigate C&C teams, or more specifically C&C dyads. Dyads are the smallest group unit, in that there are only two individuals. In many cases, these dyads have independent tasks but need to monitor each other and backup when necessary. Here, the question arises how the mentioned interpersonal distance influences these teamwork behaviours. In addition to that, it is also important how the members perceive the distance to carry out their tasks. In other words, what distances people prefer for tasks that are designed to include behaviours like monitoring or feedback. A comfortable interpersonal distance is crucial for these dyads to work comfortably and efficiently (Sundstrom & Altman, 1976).

Previous research suggests a change in superficial behaviour like eye contact or how personal distance changes based on several factors (Russo, 1975; Uzzell & Horne, 2006). However, this research did not focus on how the difference in interpersonal distance influences teamwork behaviours such as monitoring or backup behaviour. In order to design a sufficient and satisfying work environment for dyads it is crucial to investigate what the preferred interpersonal distance is.

This paper aims to identify the preference of personal distance in dyads that have experience of working together and exercise mutual performance monitoring and backup behaviours. As mentioned earlier, previous research describes the impact teamwork processes have on performance. Therefore, this paper focuses on interpersonal distance because it is an important factor of working environments. On such ground, it is important to find out how people perceive interpersonal distance.

Hence, we designed an experiment in which participants can choose a preferred distance from a team member in a virtual environment (VE). Virtual environments have the opportunity to control each variable in great detail (Bailenson, Blascovich, Beall & Loomis, 2003). The experimental setup can be designed in a way that is as close to the real environment as possible without having great costs or making changes to the real world.

However, it is important to consider the way people perceive distances in virtual environments. Waller (1999) states that distances in virtual environments are often overestimated. Ng, Chan, and Lau (2016) showed that 40% of their participants underestimated the distance. There is a general misperception of distances in various virtual and augmented environments (Witmer & Kline, 1998). Visual cues are often misinterpreted, and the scientific world is still optimizing the perception of distance in these environments. Nevertheless, this distortion in perception does not mean that it is impossible to infer valid data from experimenting with a virtual environment. Sundstrom and Altman (1976) described these types of experiments as simulation methods. They state that these methods are valid and empirical and are useful to grasp the reality.

The way people perceive distances in a virtual environment is influenced by the perspective and novelty of the environment (Steinicke, Bruder, Hinrichs, Lappe, & Ries, 2009; Phillips, Ries, Kaeding, & Interrante, 2010). Philips et al. (2010) state that distances are perceived as more accurate when seen in the Point of View (or first-person; POV). Another important factor they mention is embodiment which means that a realistic avatar of oneself can help perceive distances more accurately. Besides, the novelty of the environment is a factor that leads to a general over or underestimation of distances. Steinicke et al. (2009) add that POV perception in virtual environments is compressed.

In order to respond to these issues, we decided to include two kinds of stimuli: stimuli in Bird's-Eye View and stimuli in Point of View. This allows to find out whether both standpoints have similar or systematically different perceptions of the same interpersonal distance. Hence, individuals must take different perspectives during the experiment. People in traditional dyads will not work or perceive things from the Bird's-Eye View. However, the Bird's-Eye View is a practical perspective to evaluate the room design, and the comparison of the two perspectives can demonstrate whether the perception of distance is the same.

Methods

Participants

The sample of the current study consisted of 177 participants. However, 107 participants did not finish the questionnaire. Thus, the final sample consisted of 70 participants, of which 32.9% were male (n = 23), 64.3% were female (n = 45), and 2.9% chose other (n = 2). The ages of the participants varied between 18 and 65 (M = 26.33; SD = 10.233). By using the convenience sampling method, 30 participants used the University internal Sona-system test subject pool to participate in the study, whereas 40 people were reached out through social media or phone calls. To take part in the study, participants had to be proficient in English. This study was approved by the Ethics committee of the University of Twente.

Materials

Figure 1. Example of a stimuli comparison for the Point of View condition.

Figure 2. Example of a stimuli comparison for the Bird's-Eye View condition.

A questionnaire was used to find the preferred interpersonal distance for each individual. The questionnaire contained 90 different comparisons of two pictures placed into two different conditions. Presented stimuli were randomized and both conditions used the same order. Both conditions included the same stimuli but from a different perspective. Meaning, the first 45 comparisons were two pictures that were in the first-person view and the second 45 comparisons were depicted in Bird's-Eye View. There was no comparison between individual pictures of the two conditions. In other words, POV pictures were only compared with other POV pictures and the same applies to the Bird's-Eye View pictures. The stimuli showed a person next to the participant working on a screen. In the Point of View condition, only the other person was shown and not the participant herself/himself (see Figure 1). Whereby, in the pictures with Bird's-Eye View both the other person and the participant were shown (see Figure 2). For both conditions, there were 10 pictures each that changed the distance between the depicted person and the participant. Every picture of one condition was compared with all the other pictures of that condition. The range of distance between the simulated team member and the participant started from 75cm and went up to 300cm at 25cm increments. Furthermore, the questionnaire provided a detailed context for the situation illustrated in the pictures. The questionnaire was conducted using the participants' home computers.

Design

This online experiment used a 2 (distance: 75 cm to 300cm) x 2 (difference in perspective: Bird's-Eye View vs. Point of View) within-groups design. The independent variables were the 'distance' and the 'difference in perspective' whereas the dependent variables were the 'selected preference of distance' and 'estimated distance'.

Procedure

First, participants were informed about the context and had to consent to the study's conditions. The participants had to imagine that they work in a pair with a team member whom they trust and worked with for a long time. Furthermore, both had an interdependent task, meaning that if the other team member had a high workload the participant should be able to react and help out. Since this study was carried out during the coronavirus pandemic, the participants were instructed to ignore the virus while conducting this experiment. After consenting, participants were presented with the stimuli and had to decide which distance they preferred (pairwise comparison). In the early stage of the questionnaire participants had to estimate the distance between themselves and the depicted partner for each shown picture. For this, a trackbar was shown starting with 0 cm and ending at 400cm. The participants were able to slide the bar to every distance between 0cm and 400cm (see Appendix C). However, less than 20% filled out the questionnaire completely because it took too long to finish. Therefore, we omitted the distance estimation after data from 29 participants was collected. Lastly, participants were thanked for their participation.

Results

Distance estimation

Participants had to estimate each distance in order to account for distortion in the perception of distances in virtual environment. For this reason, the mean of each estimated distance was computed and compared with the actual distance. First, it is important to find out whether there is a significant difference between the estimated distances and the actual distances. That is why a One-Sample t-test was carried out. Table 1 shows the outcome of that analysis for the POV condition and Table 2 for the Bird's-Eye View condition. The analysis clearly demonstrated that there is a significant difference between the estimated distances and the actual distances. All the p-values have a significant value which showed a significant difference.

Table 1.

Results of the t-test including Mean, T-value, Degrees of Freedom, and p-value for Point of View.

Distance (cm)	*M*	*T*	*Df*	*P-Value*
75	39.73	-9.64	28	<0.001
100	56.28	-9.76	28	<0.001
125	79.67	-8.77	28	<0.001
150	85.41	-10.32	28	<0.001
175	98.54	-11.34	28	<0.001
200	116.30	-10.95	28	<0.001
225	126.97	-10.87	28	<0.001
250	141.93	-11.22	28	<0.001
275	168.87	-9.46	28	<0.001
300	182.72	-9.54	28	<0.001

Table 2.

Results of the t-test including Mean, T-value, Degrees of Freedom, and p-value for Bird's-Eye View.

Distance (cm)	*M*	*T*	*Df*	*P-Value*
75	27.46	-13.68	28	<0.001
100	51.04	-11.47	28	<0.001
125	75.42	-10.23	28	<0.001
150	94.18	-10.54	28	<0.001
175	109.70	-10.90	28	<0.001
200	134.75	-8.50	28	<0.001
225	149.47	-9.12	28	<0.001
250	164.16	-9.30	28	<0.001
275	187.64	-8.39	28	<0.001
300	206.60	-7.27	28	<0.001

Depicted in Table 3 are the means and standard deviations of the participants' distance estimations of the Point of View perspective. Table 4 presents the means and standard deviations for the participants' distance estimations of the Bird's-Eye View perspective. Both tables also include the distortion factors by which the participants underestimated the distances on average. This was computed by dividing the Mean of the distance estimation by the actual distance. If this value is close to one, it would mean the participants estimated the distances correctly. Furthermore, the mean of all distortion factors in the POV condition equalled to 0.59 and 0.61 in the Bird's-Eye View condition. Meaning they underestimated the distances by the factor 0.59 in the POV and 0.61 in the Bird's-Eye View.

Table 3.
Means, SDs, and the Distortion Factors of the distance estimation for Point of View.

Distance (cm)	*M*	*SD*	*Distortion Factor*
75	39.73	19.71	0.53
100	56.28	24.11	0.56
125	79.67	27.86	0.64
150	85.41	33.70	0.57
175	98.54	36.30	0.56
200	116.30	41.15	0.66
225	126.97	48.58	0.56
250	141.93	51.89	0.57
275	168.87	60.43	0.61
300	182.72	66.18	0.61

Table 4.

Means, SDs, and the Distortion Factors of the distance estimation for Bird's-Eye View.

Distance (cm)	*M*	*SD*	*Distortion Factor*
75	27.46	18.72	0.37
100	51.04	22.98	0.51
125	75.42	26.10	0.60
150	94.18	28.51	0.63
175	109.70	32.25	0.63
200	134.75	41.34	0.67
225	149.47	44.60	0.66
250	164.16	49.70	0.66
275	187.64	56.11	0.68
300	206.60	69.16	0.69

Multidimensional Scaling Analysis

The raw data of the participants was used to create a preference matrix for both categories (see Appendix A). For that, we first computed a preference matrix by giving the value 1 if the participant preferred the smaller distance and 0 if the participant preferred the larger distance of the two distances depicted in the pictures. We then summed the results of all participants for each comparison, making it two matrices for the two conditions with 45 comparisons each. Regarding a preference matrix, absolute similarities are demonstrated if 50% prefer on option and 50% prefer the other option. In this case, 50% equals to a score of 35 because 35 is half of the participants. The preference matrix was the basis for the distance matrix. On the other hand, in a distance matrix the value of similarity is 0. That is why 35 was subtracted from every value. Subtracting 35 from each value meant that the new values demonstrated the distance from 35. The absolute values were used to determine the distance from absolute similarity. Therefore, the highest value and therefore the highest dissimilarity in our distance matrix was 35 and the highest similarity was 0 (see Appendix B).

Bird's-Eye View

A Multidimensional Scaling Analysis (MDS) was carried out. The Scree Plot showed that for the Bird's-Eye View condition two dimensions have a stress value that is below 0.1 (see Fig. 3). Lower stress levels are generally desired because they demonstrate that the distances between individual points have higher conformity with the actual computed multivariate distances. Besides, the stress level indicates how many dimensions are acceptable for interpretation while also depicting distances accurately in the Common Space plot (Kruskal & Wish, 1978). The Common Space plot shows the similarity between each distance mark (see Fig. 4). It shows that the distances of 75cm, 100cm, and 125cm are all packed together around point 0. The other distances are making a circle around these three distances. 75cm is the closest to the point 0. Longer distances like 300cm, 275cm, and 250cm are rather high in either dimension 1, dimension 2, or both dimensions.

The distance matrix shows that 75cm is perceived as similar in preference when compared with larger distances and lower in similarity when compared with distances ranging from 100cm to 150cm (see Appendix B). Furthermore, the preference matrix shows that 75cm is preferred over distances from 250cm to 300cm and not preferred over smaller distances from 100cm to 175cm. Nevertheless, overall 75cm seems to be very similar perceived when compared to the other distances. The distance matrix shows that, even when compared with the smaller distances the divergence is small compared to the divergence of other comparisons.

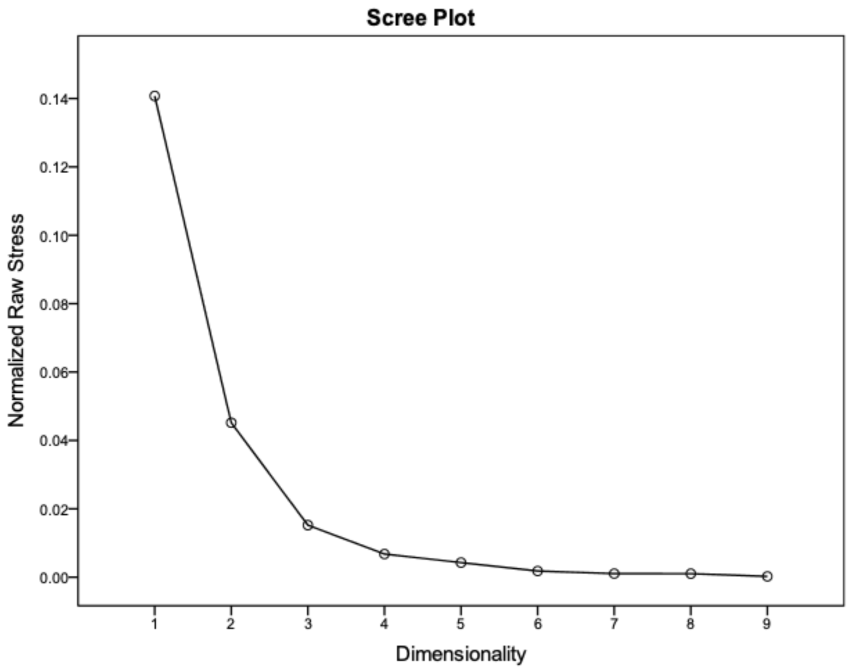

Figure 3. Scree Plot for determining the correct number of dimensions (Bird's-Eye View condition).

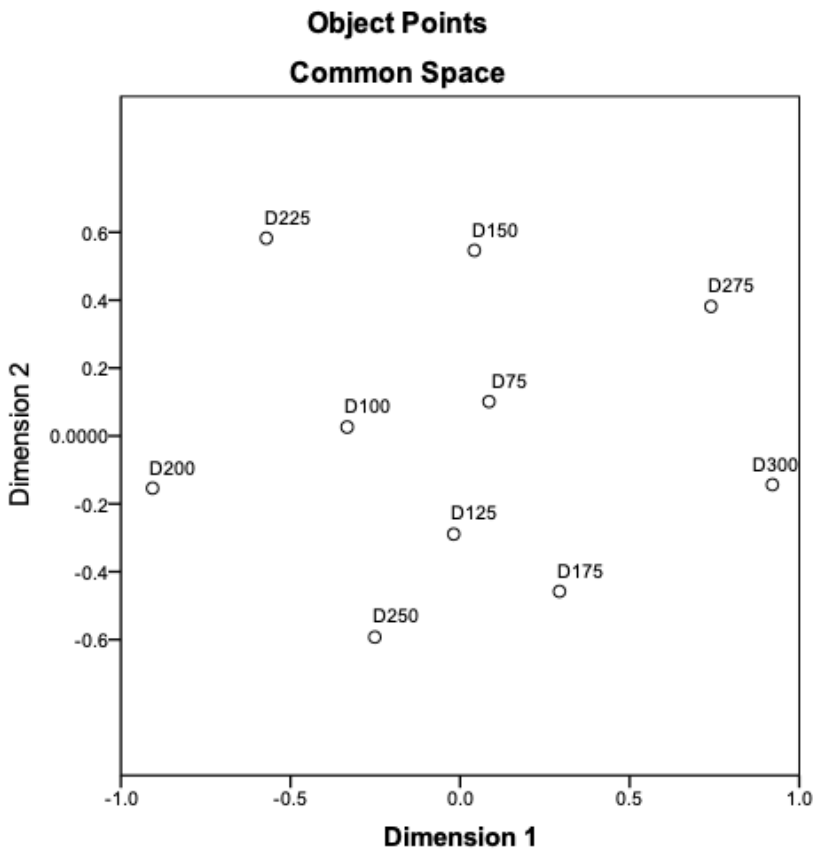

Figure 4. Common Space Plot that shows similarities and dissimilarities between the different distances (Bird's-Eye View condition).

Point of View

Again, a multidimensional scaling analysis was carried out and the Scree Plot showed that with two dimensions the stress is <0.1 and therefore low enough (see Fig. 5). After that a Common Space plot was computed which showed that longer distances like 300cm, 275cm, and 250cm have a high dissimilarity with the other distances. The other values are clustered together to the left and form a circle. The value of 100cm has the highest similarity to the other distances and is very close to the point 0 on both dimensions. The distance matrix supported this by showing high similarity and close to equal amount of preference and non-preference (see Appendix B).

Another interesting finding is presented in the preference matrix where the distance of 75cm is clearly not preferred over any other distance. However, a nearly equal number of participants preferred either 125cm or 75cm. The distance of 125cm was preferred over all other distances and was only nearly equally distributed when compared to 75cm or 150cm. 75cm is also the only distance that participants did not prefer over 300cm (see Appendix A).

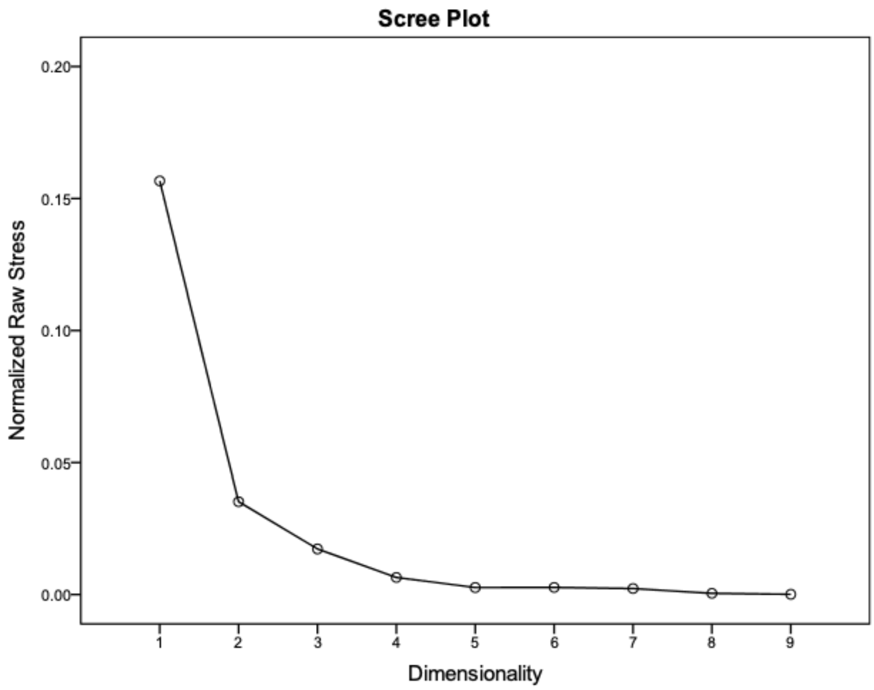

Figure 5 Scree Plot for determining the correct number of dimensions (Point of View condition).

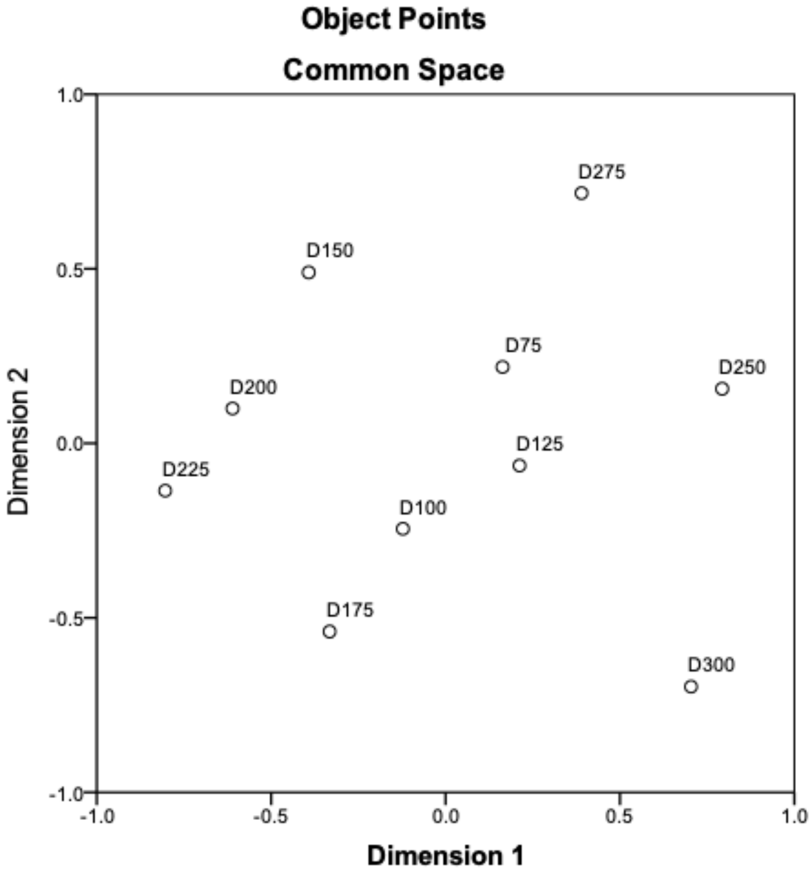

Figure 6. Common Space Plot that shows similarities and dissimilarities between the different distances (Point of View condition).

Discussion

The overall aim of this paper was to find the preferred interpersonal distance of individuals in dyads and the perception of distances in virtual environments using Point of View and Bird's-Eye View. The estimation analysis of the perception of distances demonstrated that the participants systematically underestimated the distances in the virtual environment. The t-test showed a significant difference between the estimated distance and the actual distance in both conditions. Moreover, both conditions presented a similar distortion factor by which the participants underestimated the distances. This factor is 0.59 in the POV condition and 0.61 in the Bird's-Eye View condition.

It is important to mention that the dimensions of the Common Space Plots in the MDS give information about how much a distance is deviating from absolute similarity. Therefore, a distance that would be located exactly on the point 0 is perceived as being completely similar to all other distances. A distance that is close to this point is perceived as more similar to the overall combination of distances than a distance that is far away from point 0.

The results show that in the Bird's-Eye View, participants perceived smaller distances, ranging from 75cm to 125cm to be similar (see Appendix B). Further, they perceived these distances as equally preferable as compared to other distances not including 125cm. The plot shows that the three distances, ranging from 75cm to 125cm, are grouped together in the middle and all the other distances circle around them (see Fig. 4). This means that participants perceived these three distances similarly preferable. The preference matrix showed that other distances were labelled as less preferable when working on tasks in a two-person team. Besides, 125cm was preferred over every other distance in the Bird's-Eye View condition (see Appendix A).

The Point of View analysis shows a similar picture when focusing on smaller distances. The interpersonal distances of 100cm and 125cm are the most preferred by the participants (see Appendix A). However, other distances ranging from 150cm to 200cm are also similar to the lower levels when compared to higher values from 250cm to 300cm which were perceived as less preferable and low in similarity. This also holds true for the Bird's Eye View condition, in which larger distances from 250cm to 300cm were also perceived as less preferable.

In both conditions, the distance of 125cm was the most preferred interpersonal distance. Nevertheless, the distances of 100cm and 150cm were only perceived as less preferable when compared to 125cm. When comparing 100cm and 150cm, 100cm was preferred in the POV condition and 150cm in the Bird's-Eye View condition.

The analysis of our sample did not show that there is a difference in how people perceive interpersonal distances based on their perspective. It seems that larger distances were generally perceived as less preferable in both conditions. Moreover, there is a clear group of preferred distances ranging from 100cm to 150cm. Since Multidimensional Scaling is more accurate when it comes to dissimilarities, we can infer that the depicted similarity of 75cm with distances ranging from 100cm to 150cm can be a distortion of the MDS (Kruskal & Wish, 1978). Here, other grouping analyses like cluster analysis can help to find out whether these similarities are actually represented by the data set. On the other hand, larger distances are presented more accurately in MDS and showed that distances ranging from 250cm to 300cm were not perceived as similar to other distances (Kruskal & Wish, 1978). In addition, the preference matrices displayed lower preferences of these distances in both conditions (see Appendix A). Based on these findings we can infer that smaller interpersonal distances are overall preferred over larger distances in both conditions.

However, the preference and distance matrices of the POV condition showed interesting results concerning the distance of 75cm. Here, the distance was perceived as being highly similar to distances ranging from 175cm to 300cm and not when compared to distances from 100cm to 125cm. Besides, the distance of 75cm was not preferred over any distance in the POV condition (see Appendix A). When comparing these results to the Bird's-Eye View condition, it showed a different picture. The distance of 75cm was perceived as similar to the distances 200cm and 225cm. Furthermore, the preference matrix revealed that the 75cm as an interpersonal distance was preferred over larger distances ranging from 250cm to 300cm and not preferred over distances from 100cm to 175cm. These findings demonstrate the only mentionable difference between the two conditions. The reason for these findings could be that 75cm is perceived as too intimidating in the POV condition. Further, this is supported by research stating that distances in first-person or Point of View are perceived as compressed (Steinicke et al. 2010).

The results showed that there is a big difference in preference and a low similarity when comparing large distances (e.g. 300cm and 275cm) with each other in both conditions. One might assume that these comparisons result in high similarity because both distances are very close to each other. However, this is not the case. The reason for this outcome could be that in this segment of the distances (last third of the distances), smaller distances, even if only a little bit smaller, are generally preferred because the distance is closer to the desired interpersonal distance.

Our findings of a preferred interpersonal distance of 100cm to 150cm are in line previous research that found that an interpersonal distance of 120cm to 180cm is the preferred distance for people to have meaningful exchanges (Thompson, Aiello & Epstein, 1979). In their experiment, they also used a virtual environment and showed videotaped interaction situations. Another study claims that people sitting side-by-side, like in this study, prefer an interpersonal distance of about 170cm (Sommer, 1962). In our experiment, the distances of 100cm, 125cm, and 150cm are most preferred. However, the findings of Sommer (1962) do not correspond with a task-related relationship between the people. In other words, their experiment did not focus on task-related interaction between participants. In our study, the participants were instructed to imagine a working relationship with their team partner. Hence, the factor of a task-related relationship was not included in the experiment of Sommer (1962).

Kinoe (2018) found that the average interpersonal distance between people is smaller when they engage in a cooperative task together. Furthermore, he contradicts the findings of Sommer (1962) that state a preference for larger interpersonal distance when people sit side-by-side. Kinoe (2018) found that people have a smaller distance when sitting side-by-side. In his experiment, he studied interpersonal distance in a real-world cooperation situation. This is in line with our findings that people choose a smaller interpersonal distance based on the context of working in a two-person team. Tedesco and Fromme (1974) support the claim that people prefer a smaller interpersonal distance when they cooperate with someone. They conclude that the variable of cooperation alone is the reason why individuals chose a smaller interpersonal distance. These findings support our results and underline the importance of external factors when studying interpersonal distance.

Nevertheless, there is evidence that the perception of distances in virtual experiments is distorted. Jansen-Osmann and Berendt (2002) state that individuals have physical distance distortion when being in a virtual environment. This general underestimation of distances in virtual environments is supported by the findings of Ng, Chan, and Lau (2016). The estimation analysis of this study concluded that distances were underestimated with a factor of about 0.6. Previous research only focused on the fact that the perception of distances is distorted. However, there is no clear factor by which designing a virtual environment is supported. Therefore, it is important to find out whether the factor of 0.6 is applicable for designing virtual environments. Nevertheless, Jansen-Osmann and Berendt (2002) also conclude that virtual environments are a trustworthy tool to study perception and with increasingly better technology are great for many purposes. The results of this study also support this claim because the perception of all distances is distorted by a similar factor (see Table 3 and 4).

Besides, the results can be utilized to design more efficient and comfortable virtual environments. Here, the distances ranging from 100cm to 150cm are important to include when team members are sitting side-by-side. In addition, virtual learning environments that are designed to simulate real environments have to include the distortion factor in the design process. Since distances are perceived differently in virtual environments it is important that the perception of distances in such environments resemble the real perceptions. The study suggests that distances in virtual environments need to be larger so that individuals can use the learned skill in the real world. For instance, virtual learning environments that focus on driving or medicine can be designed in a more efficient way, so that people have a better learning experience.

The data suggests an interpersonal distance of 100cm to 150cm in a virtual environment. However, these distances are underestimated by a factor of about 0.6 in both conditions. Hence, participants demonstrated that they prefer a distance of 60cm to 90cm in the real world. Therefore, for actual traditional groups, it is important to keep this factor in mind when designing work environments. Besides, when conducting experiments on distances in virtual environments, inference into the real world is only possible when keeping in mind that the perception distances are distorted by a factor of 0.6. For C&C dyads this means an interpersonal distance ranging from 60cm to 90cm is preferred when sitting side-by-side.

Kinoe (2018) states that interpersonal distances change with the absence or presence of eye-contact or perception of eyes in the peripheral vision. This variable was not included in our 2-dimensional virtual experiment design. Nevertheless, a real-life situation would most definitely include eye-contact with the other team member. Therefore, the interpersonal distance would probably be influenced by this variable in a real environment. Furthermore, we only asked the participants to imagine that they would work on a task with their partner. Actual cognitive load is also influencing which interpersonal distance is preferred by an individual (Kinoe, 2018). In other words, having a real task-related situation is also a factor that can influence the preference of interpersonal distance.

Our experiment is a good basis for how people perceive interpersonal distance in task-related dyads. However, there are some factors that cannot be included in 2-dimensional static pictures. In order to include more variables to the picture, it is necessary to either design a completely virtual environment in which one can move around freely or make an experiment in the real world. Nevertheless, the findings of this study suggest that

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Appendices

Appendix A

These two matrices show the comparisons between all the distances. A 1 was computed when a participant preferred the smaller distance and a 0 was computed when a participant preferred the larger distance. In these matrices a number that is smaller than 35 means participants preferred the larger distance and a number bigger than 35 means they preferred the smaller distance. For instance, looking at the 300cm column of the Bird's-Eye View condition shows that all the participants preferred the smaller distance over 300cm. Since 70 individuals participated in the study 35 means both distances were preferred by 50% each and the preference is in balance.

Preference Matrix for Bird's-Eye View condition

Distances in cm	75	100	125	150	175	200	225	250	275	300
75	0	18	21	25	27	35	36	40	43	44
100		0	28	40	43	45	47	49	57	57
125			0	48	52	56	57	54	57	56
150				0	59	57	66	62	64	65
175					0	61	62	63	61	63
200						0	59	60	67	68
225							0	59	63	69
250								0	57	61
275									0	55
300										0

Preference Matrix for Point of View condition

Distances in cm	75	100	125	150	175	200	225	250	275	300
75	0	11	34	15	20	20	31	27	34	32
100		0	24	31	36	36	40	41	51	50
125			0	43	42	49	53	56	57	56
150				0	44	55	55	61	61	64
175					0	54	58	61	65	63
200						0	54	64	63	66
225							0	65	63	65
250								0	57	62
275									0	64
300										0

Appendix B

The two matrices show the distance from 35 of each comparison. Values range from 0 to 35. This means the matrices show the distance from absolute perceived similarity of preference, since 35 is half of the participants. In these matrices the value 0 means that the two compared distances are perceived similar in preference when taking into account all 70 participants. On the other hand, the value of 35 or higher values in general show that participants perceived a difference in similarity of the two compared distances. For example, the comparison between 75cm and 200cm in the Bird's-Eye View condition demonstrate that these two distances were perceived as similar. 300cm and 225cm, on the other hand, were perceived as very dissimilar because the value 34 is very close to 35.

Distance Matrix for Bird's-Eye View condition

Distance in cm	75	100	125	150	175	200	225	250	275	300
75	0	17	14	10	8	0	1	5	8	9
100		0	7	5	8	10	12	14	22	22
125			0	13	17	21	22	19	22	21
150				0	24	22	31	27	29	30
175					0	26	27	28	26	28
200						0	24	25	32	33
225							0	24	28	34
250								0	22	26
275									0	20
300										0

Distance Matrix for Point of View condition

Distances in cm	75	100	125	150	175	200	225	250	275	300
75	0	24	1	20	15	15	4	8	1	3
100		0	11	4	1	1	5	6	16	15
125			0	8	7	14	18	21	22	21
150				0	9	20	20	26	26	29
175					0	19	23	26	30	28
200						0	19	29	28	30
225							0	30	28	30
250								0	22	27
275									0	29
300										0

Appendix C

Introduction to the questionnaire (first page of the questionnaire)

Thank you for your interest in this study about room design of work environments. In the following questionnaire you will be asked to compare two pictures of environmental setups and to indicate your preference.

Please, read the following information carefully.

By proceeding to the next page, I agree to the terms. I understand and confirm that...

- my participation is voluntary
- I was informed about the right to refuse to answer questions and the possibility to withdraw from the study at any time without justification.
- the data obtained during this study will be treated confidentially.
- collected data is exclusively used for this study and is presented anonymously.
- any personal data that can help to identify me, will not be shared beyond the research team.

If there are any questions or you are interested to be informed about the results of this study, please contact:
m.dammann@student.utwente.nl

Demographics (second page of the questionnaire)

Please, answer the following question about your person.

What is your age?

What is your gender

- ○ Male
- ○ Female
- ○ Other

Context to the questionnaire (third page of the questionnaire)

This study is about personal distance. More precisely, it aims to assess the subjective feeling of comfort with the distance between you and another person in a team work situation. However, this perception of comfort might be changed due to the Corona Virus, which is not part of this study. Therefore, imagine the following case:

Think back to the times before we had to take care of interpersonal distance due to the Corona-Virus. Therefore, you do not need to do social distancing, meaning to keep a distance of 1,5m between you and others. Being closer to others would not be a risk to your health in this particular study.

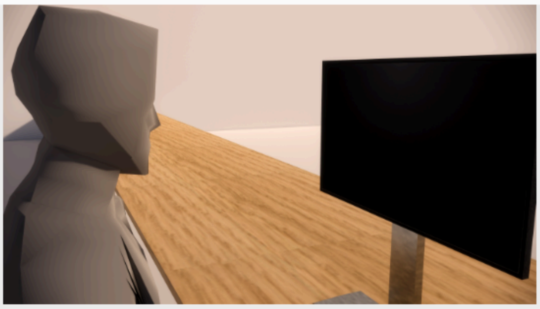
Based on that, imagine you are part of a two-person team. You know your team partner well and you work together every day. Your work is interdependent, which requires that you and your partner check upon each other's work, support each other and make decisions together. Therefore, you should be able to watch your partner's desktop and to communicate with each other.

Keep this in mind when you answer the following questions.

Example question of the Point of View condition

These pictures show you and your team member's workplace. Both pictures were taken from your perspective. With this case in mind, please compare the two environmental setups and indicate which one you perceive as more comfortable in the light of interdependent teamwork.

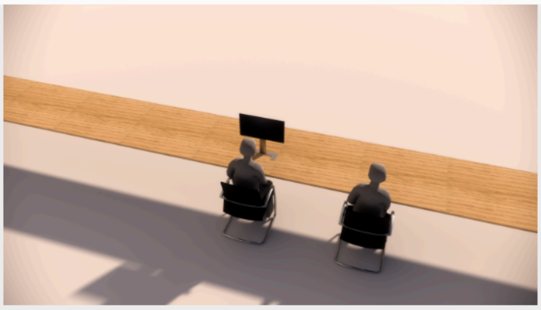
Which environmental setup for teamwork do you like better? Click on the picture you prefer.



Example question of the Bird's-Eye View condition

These pictures show you and your team member's workplace. Both pictures were taken from the bird's eye perspective. With this case in mind, please compare the two environmental setups and indicate which one you perceive as more comfortable in the light of interdependent teamwork.

Which environmental setup for teamwork do you like better? Click on the picture you prefer.



Example question of Distance Estimation (both conditions)

Please, look at each picture separately. How large would you estimate the distance to be between you and your team partner in centimeters? Indicate the distance by moving the cycle below the scale.

0 40 80 120 160 200 240 280 320 360 400

estimate the distance for the left picture