KEEP TALKING AND NOBODY EXPLODES:

A qualitative study on nonverbal communication factors identified in a group problem-solving task

Lara van Wijk
Psychology student at the University of Twente

Supervisor: Prof. Dr. J.M.C. Schraagen
Professor at the University of Twente

Abstract

The aim of this study was to discover nonverbal communication factors that are necessary for successful remote collaboration in diminished reality. Nowadays there is a severe shortage of technically trained staff that are able to carry out, for example, maintenance or repair tasks. AR is a new technology that might a provide a solution to solve this gap in the job market. A between-subjects sign was employed to find the differences between a close collaboration condition, where participants could see each other, and a remote collaboration condition, where participants could not see each other but were only able to talk with each other for communication. Participants played the game Keep Talking and Nobody Explodes in groups of three, where participants had to defuse a virtual bomb. Two participants handled the Bomb Defusal Manual and one participant played the bomb defuser. Communication was categorised with a coding scheme which had the following main categories: pointing, gesturing, cross-checking and nonverbal answers. Pointing in a manual for a fellow participant was the only code that was statistically significant (p=0,016). This means that it occurred more in the remote collaboration condition. Cross-checking neared significance but did not reach it (p=0,056). For all other codes there was no difference between the remote and close collaboration groups. This is not in line with previous literature on the topic. Possible reasons for these results are a significant difference in age between the groups and outliers in the data that may be caused by personality or age.

Nowadays technology is everywhere around us and it is quickly evolving. Since technology will play a big role in the future, many investments are made into the industry. This has the effect that technology is developed to be bought commercially, meaning that it does not have to be expensive anymore. An example of such an affordable form of technology is Augmented Reality (AR), more specifically AR glasses. AR glasses are mixed-reality head-mounted devices (HMD) that allow the user to have an experience in which the real world, for example a table, is overlaid with a 'virtual' aspect, for example a virtual prototype displayed on a real-world table. Examples of AR glasses that are developed and are widely available to the public are the Aryzon (€30; Aryzon – 3D Augmented Reality Headset, n.d.) and the HoloLens 2 ($3500; HoloLens 2, n.d.). Aryzon is focused on making the device affordable to the public for mainly entertainment purposes, whereas Microsoft's HoloLens 2 advertises it as a business solution (Aryzon – 3D Augmented Reality Headset, n.d.; HoloLens 2, n.d.). AR glasses are an example of augmented remote collaboration support. Nowadays there is a shortage of technically trained staff (Binvel, Franzino, Guarino, Laouchez, & Penk, 2018), but AR glasses might be a potential solution to solving this issue through augmented remote collaboration. Take for example a novice that works on a navy vessel. In a maintenance task on a machine the technician can get assistance from an expert on shore who provides the correct verbal instructions combined with visual cues, such as boxes around areas that need to be worked on. Using AR glasses this way means that a number of issues arise that need to be addressed. This paper will focus on important factors in communication for augmented remote support. It is then also important to consider that there exists an asymmetrical relationship between the expert (or *helper*) and the novice (or *worker*), as was stated by Gurevich, Lanir, and Cohen (2015). It is defined as asymmetrical because the expert has most of the knowledge and the novice has the tools, the environmental overview, etc. This can lead to difficulties, which will be specified later.

Communication in remote collaboration can lead to challenges for the team that is working on something. This is especially true for nonverbal communication (Fletcher & Major, 2017). Because you are unable to see each other you cannot pick up on nonverbal cues, which leads to members of the team monitoring each other's performance more. Herein also lies a difficulty because you can often tell much from, for example, someone's facial expression or gestures that are made.

In order for remote collaboration in AR to be successful a number of elements need to be present. Firstly, there needs to be a shared visual context. This is an important factor as it allows for the grounding of communication. This "*improves coordination, facilitates common ground, and provides a shared understanding of what is being discussed"* (Gurevich et al., 2015, p.528). Secondly, the novice needs to see the hand gestures of the expert as this enables gesture recognition. Gesture recognition allows for an improved effectiveness, fewer errors and in general an improvement of communication that happens between the novice and expert (Gelb, Subramanian, & Tan, 2011; Gurevich et al., 2015). Thirdly, using AR for collaboration should be intuitively oriented. In order for the product to be usable it should adhere to how people would 'naturally' communicate and interact with each other. The advantage of AR in this respect is that the user can follow his or her intuition of, for example, wanting to point at something (Gelb et al., 2011). Fourthly, the video quality needs to be high and the field of view (FOV) needs to as wide as possible. This ensures that the expert maintains situational awareness, which contributes to help build a mental model of the environment that the novice is working in (Darken & Peterson, 2002). Mental models are especially important for novices because they help with problem-solving (Kieras & Polson, 1985).

A complicating factor in the use of augmented remote support is the division of attention that is required of the novice. Attention is the selection of input from all the senses to determine which information will be further used for processing and which information will not (Smith, Kosslyn, & Barsalou, 2007). The novice needs to be able to properly divide his or her attention between the task at hand and the directions that he or she gets both via auditory and visual information. However, what the novice can attend to is limited by Working Memory. Working Memory has a very limited capacity, only 3 to 5 items, meaning that the information provided by the expert needs to be clear and concise so as not to strain Working Memory further (Johnson, 2014). The information from the expert can then be combined with the knowledge and the skills that the novice already has. It is important for the expert to use terms and actions that the novice already has as neural memory patterns. Activating a neural memory pattern can trigger recognition, for example of the novice's training in performing the task he or she is working on. This leads to a better comprehension of the task, which means that the task can be carried out faster and with fewer errors (Johnson, 2014). This is especially important for recognizing action sequences which can be found in procedural memory. If the expert is able to trigger the action sequences in the novice's memory, this can greatly enhance their communication and ability to successfully complete the task. Johnson (2014) also proposes that when giving instructions, one should not give the entire sequence at once, but do it step by step. This ties into the fact that experts need to be clear and concise in their communication to the novice. All in all, the expert needs to give clear and concise instructions, give instructions step-by-step and try to trigger already existing actions sequences of the novice. A suggested tool that the expert can use for this is a checklist for specific tasks, which also make for better guidance of the novice.

There is some research on AR and factors that are needed for successful collaboration using AR. Some of this work is mentioned above, such as the article by Gurevich and colleagues in 2015. However, there have not been many studies that have looked explicitly at nonverbal communication factors that are essential to good communication in remote collaboration. This study will focus on the identification of such nonverbal communication factors in a problem-solving task. It will provide insights into what developers and users of augmented remote collaboration support should pay attention to in the future in order for it to be used to the best of its abilities. This topic has an important societal relevance due to the shortage of technically trained staff (Binvel et al., 2018). If remote collaboration via AR turns out to be as or more successful than only employing highly trained technical staff, it is a good solution to narrow the gap in the job market. It is also a solution that can lead to shorter task completion times because during a shift technicians can spend 45% of their time searching for and reading manuals with instructions (Braly, Nuernberger, & Kim, 2019). Using AR can reduce this time by employing an expert who does not have to search for and read the whole manual on site. Since some tasks are very time-sensitive this is also an important factor to consider for choosing to use AR. There is also scientific relevance to this topic as this has not yet been studied before. Different studies, such as the one by Gelb and colleagues (2011), touched upon factors that are important in the use of AR in collaboration. However, there has not been a study that focuses solely on explicitly stating which factors are important for AR to be successful and which need to be incorporated into the technology. Additionally, a call is made to use a between-subjects design as in studies about AR, within-subjects design are dominant (Dey, Billinghurst, Lindeman, & Swan, 2018). Within-subject designs can lead to issues because participants can have pre-existing knowledge of the technology and/or of the task. In this way, measures may only be focused on the differences for specific participants rather than to give an insight for a broader population. Therefore in this research the choice has been made for a between-subjects design that distinguishes between a close collaboration condition, which reflects a situation where colleagues are eye to eye, and a remote collaboration condition, which reflects a situation where colleagues cannot see, but instead just hear each other. This is more reminiscent of a real-life work situation where you need to be able to work with a number of different colleagues in a number of different environments. The aim is then to see what happens when team members work together in a diminished reality situation, i.e. taking away nonverbal communication. This leads to the following research question:

"What nonverbal communication factors can be identified in team problem-solving tasks?"

Method

Participants

The sample consisted of 30 participants (20 male, 10 female), with 15 participants in each condition. Within the conditions participants were divided into groups of 3 participants based on availability. The mean age of the close collaboration condition was 22 (SD = 2,88). For the remote collaboration condition the mean age was 35 (SD = 13,59). The difference in age between the groups is significant (t (28), p<0.001). In the close collaboration group 33,3% of participants was Dutch and 66,6% was German. In the remote collaboration group all participants were German. Furthermore, 3 participants had previously played the game, of which 2 were in the close collaboration group and the other one in the remote collaboration group. The only selection criterion for participants was to be able to have sufficient knowledge and skills of the English language. However, an exception was made for participants gathered a by fellow researcher. The sample was gathered in the personal networks of the researchers, as recruiting via the University of Twente test person system did not deliver any sign-ups to participate in the study. Ethical approval was obtained via the Ethical Committee of the BMS at the university.

Materials

The study was performed at two locations, based on availability of the participants. One location was a secluded room at the University of Twente. The second location was the basement of a private house where the experimental set-up was copied. The game Keep Talking and Nobody Explodes was purchased and used as the task that needed to be completed (Defuse a bomb with your friends, n.d.). Along with the game came a Bomb Defusal Manual (http://www.bombmanual.com/; version 1) which was used by two of the participants. Data collection was done by collecting video material of the participants and by asking them to fill out a questionnaire with basic demographic information. Participants were filmed using a GoPro Hero 5 Session, which filmed with resolution 3840x2160 and in high quality.

Design

The study used a between-groups design. In one condition (close collaboration), participants performed the task in the same room at a round table or a set-up that mimicked a round table. In the other condition (remote collaboration) participants worked in a room that was split by a makeshift wall which did not allow participants to see each other anymore. They could only communicate via talking.

Procedure

All participants speaking English were first informed about the purposes of the study via an information sheet and were then asked to sign an informed consent (see Appendix A and B). Participants then had to watch a series of YouTube videos (https://www.youtube.com/playlist?list=PLdC3pP79J-A9nuOv0g0oJc0uKej3E3cpT) that explained the game and the manual as a basic form of training. They did not watch all the videos, but only the modules that were included in the testing (see below). For German participants, the informed consent was translated into German, as were the game and the information sheet. As the basic form of explanation the fellow researcher showed a previously recorded video of himself where every module is solved once but with a German explanation.

All participants then started a practice session where they had to perform two simple and two complex practice-sessions. Both the explanation of the manual and the practice session were used to control for the learning effects that occur when one is new to the game. After these sessions there was no objective test, such as task completion time to measure the basic skills of the groups before they went into the trials. During the video explanations all questions of participants about the game were answered. During the practice sessions only technical questions were answered, such as how to turn around the bomb. During the trials no questions were answered.

Within the trios the defuser and instruction providers were randomly assigned. For the close collaboration condition (see Figure 2) this meant that the defuser was asked to sit in front of the laptop that had the game *Keep Talking and Nobody Explodes* opened. The instruction providers were handed the bomb defusal manual and were seated across the defuser, which did not allow them to look at the screen, but they were able to see, for example, the gestures of the defuser. The instruction providers were not allowed to perform actions on the laptop. In this condition participants could rely on both verbal and nonverbal communication with the defuser. In the remote collaboration condition (see Figure 1) the tables were set up in two rows that were divided by a screen. The defuser was seated in the back row behind a screen to mimic working at a distance. The instruction providers both had a bomb defusal manual. In this condition participants could only rely on verbal communication with the defuser.

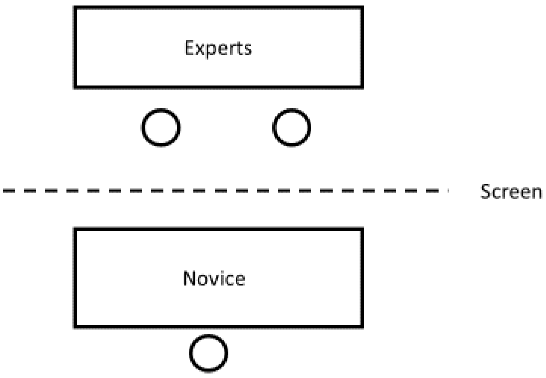

Figure 2 Sketch of Remote Collaboration Condition

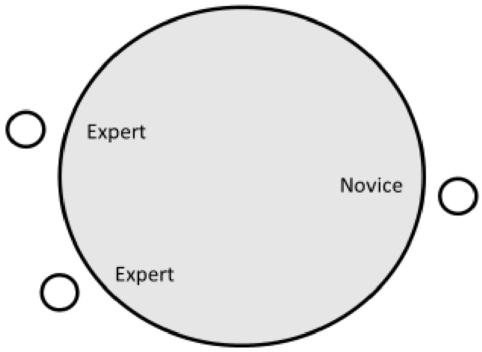

Figure 1 Sketch of the Close Collaboration Condition

After the sign to start participants had to defuse the bomb in the game. The defuser had to follow the instructions from the instruction providers which they derived from the manual. Within the game the *tutorial mode* was used to play the game. In the tutorial mode the player is guided through a series of different bombs that gradually increase in difficulty in order to learn how to play the game. This allowed for more control of the modules employed by the game as modules were chosen from a predetermined set. Per group in each condition five trials were used. The tutorial section used was called 'One step up' and displayed a number of different modules which changed each game, namely Wires, Button, Keypads, Simon Says, Who's on First, Memory and Mazes. This allowed for the game to load different iterations meaning that participants were not solving the same exact bomb each trial.

One by one the trios had to disable all the modules to disable the bomb and finish before their time was up, which was 5 minutes. If they did not finish in time or they had gathered three strikes (mistakes, e.g. cutting the wrong cable) the bomb would explode and the game was over. When participants had finished all trials, they were debriefed and thanked for their participation in the study.

Data analysis

The test-sessions and trials were filmed with the earlier mentioned GoPro Hero 5 Session and later transcribed using InqScribe. The camera, which was mounted on a small tripod, allowed participants handling the manual and sometimes the defuser to be filmed in the close collaboration condition. The defuser was also filmed with the webcam. In the remote collaboration condition, participants using the manual were filmed with the GoPro and the defuser was filmed via the webcam of the laptop that the game was run on. When all transcriptions were finished these were loaded into Atlas.ti 8 for coding. For the coding there was a focus on nonverbal communication that would be lost when the instruction providers and defuser were separated from each other. The coding scheme was developed using a largely inductive approach based on literature mentioned in the Introduction. Furthermore, the codes 'pointing in a manual to indicate location' and 'pointing otherwise' were established deductively after watching the first videos. This resulted in the following coding scheme:

<u>Gesturing</u>

Gesturing could be done between all different participants. In the close collaboration condition all participants could gesture to each other. In the remote collaboration the instruction providers could gesture to each other and the defuser could also gesture, but other participants could not see this.

1. *Type* I: Gesturing related to things in the game. For example: Gesturing what a symbol looks like from the Keypads module *or* gesturing what a module looks like.
2. *Type II*: Gesturing not-related to the game. For example: Gesturing that you want to stress the importance of what you say.

<u>Pointing</u>

Pointing is expected to happen mainly between instruction providers.

1. Pointing to the manual in order for someone else to see what is meant. For example: when participant 1, instruction provider, points to a page of participant 2's manual to indicate the correct maze.
2. Pointing in a manual to indicate a location. For example: participant 1 is pointing in the manual to keep up with the location of the defuser in the maze.
3. Pointing otherwise: for example to a fellow participant to divide tasks.

<u>Cross checking by looking</u>

Participants who have a manual are cross checking each other by looking at manuals. For example: participant 1 with the manual is unsure whether she is looking at the correct maze, so she looks at where participant 2 is on that page.

<u>Nonverbal answers</u>

Participants that nod or shake their head to answer questions or commands of the participants that control the manual.

The code was applied to all nonverbal behaviour in the transcription indicated between squared brackets, i.e. […]. These were transcribed nonverbal behaviours, e.g. [points to manual], and were considered as the unit of analysis. It was not indicated between which participants communication went. The sections were included from both the test-sessions, as the basis for the shared mental model was established there, and the trials. All sections that were coded could have multiple codes attached to it, depending on the interpretation of the researcher. Transcripts were cross-coded to assess the interrater reliability using the tool embedded in Atlas.ti.

For further analysis of the data, IBM SPSS Statistics 23 and 25 was used. This was used to take a further look at the demographics using descriptive statistics and a t-test for age. Additionally, the Mann-Whitney U nonparametric test was used to analyse differences between the conditions and their respective number of codes.

Results

Outliers and issues

In interpreting the data it must be stated that for group 1, 4, and 5 of the close collaboration condition the video of the defuser was either not filmed or there were technical difficulties with the filming. This mostly had an effect on the code gesturing and nonverbal answers. For group 1 gesturing was covered for the most part because the hand movements of the defuser were visible in the video for the people handling the manual. This occasionally occurred for group 4 and 5. However, since the number of groups per condition is small and there were no large differences, it was decided to keep them in the data set. Additionally, only after the first group it was decided that the test-sessions were also important for the full picture of how communication was established. This was, for example, obvious in communication about the Keypads module where participants often gestured to support what they were stating in their descriptions of specific symbols. Therefore, test-session coding for group 1 in the close collaboration condition is not reported.

Within the data there were some outliers. For the code 'Nonverbal answers' one group is considered as an outlier, group 2 in the remote collaboration condition. For group 2, nonverbal answers were quite evenly distributed across two of the three participants. Group 5 of the close collaboration condition and group 4 of the remote collaboration condition are also possible outliers (see Appendix C, Figure 3). Another outlier was group 4 in the close collaboration condition for the code 'Pointing in a manual for yourself'(see Appendix C, Figure 4). In this group the display of this behaviour was quite evenly distributed across the two participants handling the manual. Even though there were a number of outliers, it was decided to keep them in the data set because of the limited number of participants. The purpose of describing them here is to show the distribution of the codes.

Comparison between conditions

Firstly interrater reliability was assessed using the Krippendorff's c-alpha binary in Atlas.ti (α = 0.952). In Table 4 (see Appendix D) the distribution of the codes over the conditions can be found. A Friedman test was performed to test for statistical significance. There was no statistically significant difference between the number of codes when comparing the close collaboration condition to the remote collaboration condition ($\chi^2(2)$ = 10,714, p=0,098). The Independent Samples Mann-Whitney U Test was employed to analyse the data nonparametrically. A statistically significant difference between conditions can be seen for the code 'pointing in a manual for a fellow participant' (U=1, p=0,016). The code 'cross-checking' approached significance (U=3, p=0,056). For all other codes there was no significant difference between the close and remote collaboration condition.

Table 1

Median and Mann-Whitney U Test Statistic for the Close Collaboration and Remote Collaboration Conditions

	Close collaboration		Remote collaboration		Both conditions	
	N	Mdn	N	Mdn	Mann-Whitney U	Exact Sig.
Cross-checking	5	4	5	10	3,00	0,056
Gesturing not related to the game	5	2	5	3	11,50	0,841
Gesturing related to the game	5	11	5	5	9,00	0,548
Nonverbal answers	5	12	5	27	6,00	0,222
Pointing to manual for fellow participant	5	4	5	9	1,00	0,016
Pointing to manual for yourself	5	11	5	67	10,00	0,690
Pointing otherwise	5	1	5	0	10,50	0,690

Discussion

The aim of this research was to answer the research question: what nonverbal communication factors can be identified in team problem-solving tasks? The results showed that only pointing in a manual for someone else could be identified as being a nonverbal behaviour that occurred more often in the remote collaboration condition than in the close collaboration condition. Additionally, cross checking came very close to the same result. Pointing in a manual for fellow participants means that a shared visual context is established, which was deemed important by Gurevich and his colleagues (2015). A shared visual context is also important for establishing a shared mental model. The defuser and instruction providers not being able to see each other, as was the case in the remote collaboration condition, is a complicating factor in communication. Reason for this is that it becomes more difficult to establish a shared mental model because you do not yet have an idea of what the other person is looking at. The defuser may only know that the instruction providers have a manual but does not know what it looks like inside and thus does not know in which way he should feed information to the participants with the manual. This leads to more discussion amongst the people handling the manual because they are slower in the establishment of the shared mental model. This then explains why the instruction providers also point more in the manual. The fact that cross-checking approached statistical significance can be explained because mutual performance monitoring increases as soon as people who are collaborating are not able to see each other anymore, as was the case in the remote collaboration condition (Fletcher & Major, 2017). Because the participants could not see each other the people handling the manual started checking each other more because they were either confused or wanted to make sure they were providing the right commands so as not to note a strike on the bomb. So, pointing in a manual for someone else and cross-checking are in line with existing research. This implies that for the future development and the use of AR these are factors that need to be taken into account for the use of this technology. If persons wearing AR glasses are able to see the pointing of the person trying to explain something to them, this contributes to the establishment of a shared visual context and mental model.

The behaviours of gesturing, answering nonverbally (nodding or shaking of the head), and pointing to a manual for yourself or otherwise did not differ due to the effects of the experimental conditions. These results were mainly out of line with the expectations drawn in the Introduction. Gesturing in both forms described in the coding scheme was not significantly different in both experimental conditions. However, in literature gesturing was seen as an important factor for nonverbal communication which would be lost in the use of AR (Fletcher & Major, 2017; Gelb et al., 2011; Gurevich et al., 2015). A possible cause of this is the wide variety of topics, situations and environments within which AR can be applied. In this study it was limited to participants with a basic training and a problem solving task. There was an added difficulty in the sense that different iterations were loaded onto the bomb so participants never got the exact same bomb. However, it is also possible to perform experiments with maintenance or repair tasks, with people who are very experienced, or with a differing task difficulty. As for the nonverbal answers in the form of nodding or shaking your head, this may depend upon personality. If it is naturally ingrained in your behaviour to nod or shake your head every time you answer with ‘yes’ or ‘no’ you will display this behaviour in the tasks as well, which might also explain the two outliers in that category. The same accounts for pointing in a manual for yourself. If you are taught to keep pointing to the place on the page where you are reading, you will display this behaviour more often than someone who was not taught in this way.

A number of factors need to be taken into account that limited the usability of the results. Firstly, the age difference between the groups is significantly different. This means that the results are difficult to compare between groups because the age in the remote collaboration group was that much higher. The game requires fast learning of how the game works and how to find the right solution, mental connections need to be made between rules, and participants need to be as efficient as possible. There is also an additional pressure of the 5-minute time limit that is put on the bomb. Especially because older participants are slower in learning associations this might have influenced their communication because they had to discuss a lot (Clark, Freedberg, Hazeltine, & Voss, 2015). In terms of behaviour this can lead to, for example, more cross-checking of each other because participants do not fully understand the game yet or have difficulty putting trust in each other. However, it must also be noted that in the real world, experts are often people who are older and have more experience with working in maintenance or repair tasks. Therefore, they might not be suitable for working on the floor, but rather working at a distance as the expert. Another limitation is that after the test-sessions there was no measurement of the actual level of understanding the participants had. By having such a base measurement, more could be said about whether the training was successful and whether the participants had enough knowledge to defuse the bomb successfully. However, during the practice sessions participants did have the ability to ask any questions they had to ensure that they understood the game properly.

Practical recommendations that I derived from this study are to ensure that the task is always the same for each group so that task completion times can be used as a measure. This was not the case in this study because for the actual trials the time it took to defuse the bomb was dependent upon the different iterations that were loaded into the game. Additionally, much research can still be devoted to this topic. AR is a technology that is still fully in development, meaning that changes will be made to the technology continuously. Also, the array of tasks that can be done using AR is very big, meaning that many different tasks need to be tested. Therefore, I would like to recommend a further look at between-subjects research in AR, both qualitatively and quantitatively. This research did provide some additional insights or confirmations to the already existing body of literature on communication and AR, and the topic will remain interesting for the years to come as the technology becomes more ingrained in the business world.

References

Aryzon - 3D Augmented Reality Headset. (n.d.). Retrieved February 27, 2019, from https://www.aryzon.com/

Binvel, Y., Franzino, M., Laouchez, J., & Penk, W. (2018). *Future of work: The Global Talent Crunch*(Rep.). Korn Ferry Institute.

Braly, A. M., Nuernberger, B., & Kim, S. Y. (2019). Augmented Reality Improves Procedural Work on an International Space Station Science Instrument. *Human Factors: The Journal of the Human Factors and Ergonomics Society*. doi:10.1177/0018720818824464

Clark, R., Freedberg, M., Hazeltine, E., & Voss, M. W. (2015). Are There Age-Related Differences in the Ability to Learn Configural Responses? *PLOS ONE, 10*(8). https://doi.org/10.371/journal.pone.0137260

Darken, R. P., & Peterson, B. (2002). Spatial Orientation, Wayfinding, and Representation. Handbook of Virtual Environments. K. Stanney. Lawrence Erlbaum.

Dey, A., Billinghurst, M., Lindeman, R. W., & Swan, J. E. (2018). A Systematic Review of 10 Years of Augmented Reality Usability Studies: 2005 to 2014. *Frontiers in Robotics and AI,5*. doi:10.3389/frobt.2018.00037

Fletcher, T.D., & Major, D. A. (2017). The Effects of Communication Modality on Performance and Self-Ratings of Teamwork Components. *Journal of Computer Mediated communication, 11*(2), 557-576. https://doi.org/10.1111/j.1083-6101.2006.00027.x

Gelb, D., Subramanian, A., & Tan, K. H. (2011). Augmented Reality for Immersive Remote Collaboration. In *2011 IEEE Workshop on Person-Oriented Vision, POV 2011* (pp. 1-6). https://doi.org/10.1109/POV.2011.5712368

Gurevich, P., Lanir, J., & Cohen, B. (2015). Design and Implementation of TeleAdvisor: a Projection-Based Augmented Reality System for Remote Collaboration. *Computer Supported Cooperative Work (CSCW), 24*(6), 527-562. https://doi.org/10.1007/s10606-015-9232-7

HoloLens 2. (n.d.). Retrieved February 27, 2019, from https://www.microsoft.com/da-K/hololens

Johnson, J. (2014). Our Attention is Limited; Our Memory is Imperfect. In *Designing with the Mind in Mind*(2nd ed., pp. 87-105). Elsevier Science & Technology. doi:10.1145/2702613.2706667

Kieras, D., & Polson, P. G. (1985). An approach to the formal analysis of user complexity. *International Journal of Man-Machine Studies*, *22*(4), 365-394. https://doi.org/10.1016/S0020-7373(85)80045-6

Smith, E. E., & Kosslyn, S. M. (2007). *Cognitive Psychology: Mind and brain*(Vol. 6). Pearson/Prentice Hall.

Appendices

Appendix A: Informed consent

Consent Form for “Keep Talking And Nobody Explodes”: The influence of team communication on successful bomb defusing

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated [15/04/2019], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that taking part in the study involves a video recording of the session and the transcription of task completion times. The video recordings will be coded and deleted after the transcription of the results. The task completion times will be stored for five years after the submission of the thesis.	○	○
I understand that taking part in the study involves the following risks: time pressure, which could lead to stressful reactions	○	○
Use of the information in the study		
I understand that information I provide will be used for publication purposes of a bachelor thesis.	○	○
I understand that personal information collected about me that can identify me, such as the video recordings and demographic data, will not be shared beyond the study team.	○	○
I agree to be video recorded	○	○
Future use and reuse of the information by others		
I give permission for the task completion times and video recordings that I provide to be archived in an anonymized excel table and on a secured hard drive respectively so it can be used for future research and learning	○	○

Signatures

______________________ ______________________

Signature of participant Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_________________________ ___________________ ________

Researcher name Signature Date

Study contact details for further information:

Benedikt Glinski:

Lara van Wijk:

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-bms@utwente.nl

Appendix B: Information sheet

Dear participant,

In this experiment you are going to play the computer game “Keep Talking And Nobody Explodes”. The purpose of this game is to solve a virtual bomb with your team within a time period of five minutes. The virtual bomb consists of three different small riddles, which you need to solve in order to defuse the bomb successfully. You will occupy one of two roles which are needed to defuse the bomb, namely you are either the participant who is defusing the bomb or one of the instruction providers, also known as experts.

The participant who is defusing the bomb can see the bomb on the screen, but does not know how to defuse it. The experts will receive a manual, which includes rules on how to solve the small riddles on the bomb and defuse the bomb consequently. These rules will be communicated by the experts to the participant who is defusing the bomb in a verbal manner. Thus, you need to communicate to defuse the bomb.

The playing of the game could lead to stressful reactions of some participants, caused by time pressure. The experimental setup which also includes the stress factor was reviewed and approved by the BMS Ethics Committee.

The participation in this study is voluntary and you have the right to withdraw form the study at any point in time during the process of the study or afterwards. If you want to withdraw after the study is over you can contact us via email. If you decide to withdraw from the study during the experiment or afterwards, the collected data will be deleted and will not be used for any publication purposes.

Before the start of the experiment basic demographic information will be collected. This information includes age, gender and nationality. The data will be collected in an anonymized manner. During the experiment other data will be collected. The sessions will be video recorded for retrospective analysis purposes. The video data will be stored on a hard drive which is secured by a password. This password is only known to the researchers themselves. When the study is finished, the video material will be deleted. Additionally, after each trial of the experiment the task completion time of your team will be transcribed. The transcribed completion times will not include any personalized data. This data will be stored for a retention period of five years after the submission of the thesis. The collected data will be used for the publication of a bachelor thesis. The video data will be coded and analyzed afterwards. The task completions times are used for statistical analysis.

You have the right to inspect the collected data from the experiment where you participated at any time point. Even after the experiment has ended you can contact us in order to schedule an appointment for inspection purposes.

Contact information:

Ethics committee:
ethicscommittee-bms@utwente.nl

Enschede, 15th of April, 2019

Appendix C: Boxplots for outliers

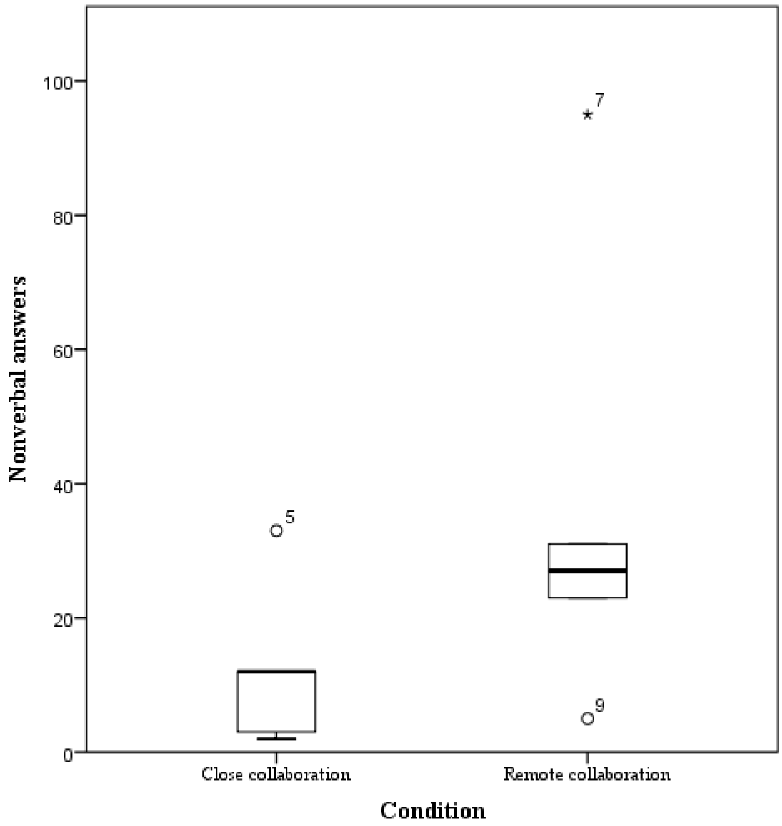

Figure 3 Boxplot Nonverbal Answers per Condition

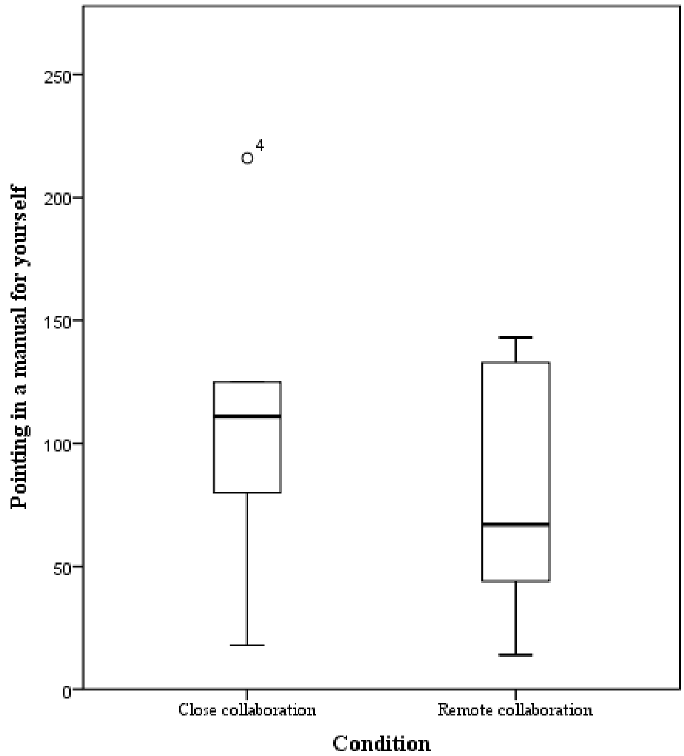

Figure 4 Boxplot Pointing in a Manual for Yourself per Condition

Appendix D: Distribution of Codes over Group and Conditions

Table 2

Distribution of Codes over Close Collaboration Condition

Codes	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	*Totals*
Cross-checking	4	4	7	10	2	*27*
Gesturing not related to things in the game	6	1	2	5	1	*15*
Gesturing related to things in the game	4	9	16	11	18	*58*
Nonverbal answers	2	12	3	12	33	*62*
Pointing in a manual for a fellow participant	4	5	2	3	7	*21*
Pointing in a manual for yourself	18	80	111	216	125	*550*
Pointing otherwise	0	1	3	1	0	*5*
Totals	*38*	*112*	*144*	*258*	*186*	*738*

Table 3

Distribution of Codes over Remote Collaboration Condition

Codes	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	*Totals*
Cross-checking	15	10	11	5	10	*51*
Gesturing not related to things in the game	4	3	8	0	2	*17*
Gesturing related to things in the game	18	15	5	3	4	*45*
Nonverbal answers	23	95	27	5	31	*181*
Pointing in a manual for a fellow participant	9	9	13	9	6	*46*
Pointing in a manual for yourself	14	67	44	143	133	*401*
Pointing otherwise	0	1	3	0	0	*4*
Totals	*83*	*200*	*111*	*165*	*186*	*745*

Table 4

Distribution of Codes across Conditions

Codes	**Remote collaboration Condition**	**Close Collaboration Condition**	*Totals*
Cross-checking	51	27	*78*

Gesturing not related to things in the game	17	15	*32*
Gesturing related to things in the game	45	58	*103*
Nonverbal answers	181	62	*243*
Pointing in a manual for a fellow participant	46	21	*67*
Pointing in a manual for yourself	401	550	*951*
Pointing otherwise	4	5	*9*
Totals	*745*	*738*	*1483*