social contexts as well as in collaborative work. If the system were to be used as a substitute for physical presence, some business meetings could be held at a distance. Using the system would in those cases contribute to a reduction of emissions caused by traveling. Further, if the system were to be used in a social context where physical presence was not an option, it could potentially improve people's mental health by providing a more immersive feeling of presence than current alternatives.

### 6.7. Building Challenges

Most challenges found in the creation of the system originated in the difference of FoV of the camera and the projector. The choice to move the camera below the projector caused problems with a chaining effect. Matching the FoV of both devices would simplify the design of the setup. However, matching the FoV between the devices could also introduce new challenges that are hard to foresee.

### 6.8. Limitations

The user study was held at one location, but in two adjacent rooms. This was done because of convenience. I had to manage the user study alone, which meant that access to both participants at the same time was essential. This could, as one participant pointed out, affect the participants' feelings of presence when using the system.

Due to the ongoing pandemic, participants were recruited through prior acquaintances. This should be taken into consideration when evaluating this paper. There is a risk that participants expressed opinions that they thought reflected my desired outcome of the research.

## 7. FUTURE WORK

The system shows promise in being a capable alternative to physically present meetings when collaborating at a distance. However, this study has only shown indications of its potential. Validating the results would increase the validity of the presented insights. This could be done by increasing the sample size, excluding participants with prior acquaintance with the author as well as applying the system in a more realistic setting over a longer period of time. Another suggestion is to improve the system further to reduce or eliminate its aforementioned inconsistencies. The improved system could be evaluated using the same method as mentioned above.

## 8. CONCLUSION

The idea of the prototype system originated in the curiosity of exploring better *Human-Computer Interaction* in spatially separated *Groupware*. A shared table surface at a distance has been explored before, but not evaluated with the *System Usability Scale* or described in depth on its design choices during its construction. Further, the focus of previous similar systems has also not been on building a system with commonly accessible and low-cost hardware. This work demonstrates that it is possible and that it is a promising tool.

The creation of the system led to insights on challenges when building such a system with commonly accessible and low-cost hardware. The results of the user study indicates that the system achieved embodiment of *workspace awareness*, good *usability* and the potential for *flow*. The system provides answers to the questions *"who, what, where, when, and how",* through natural interactions. Usability was graded highly by its users. Interviews and observations from the user study also indicate possible states of *flow*. A wide variety of perceived affordances indicates potential for the system to be used in many different situations and contexts when communicating at a distance.


## ACKNOWLEDGMENTS

I would like to thank my supervisor of this thesis, Mario Romero, for his guidance throughout the project. I would also like to thank my peers for their feedback, the participants of the user study for their contribution and lasty, a special thanks to Matilda for helping me set up the user study.


## REFERENCES


[1] Ashdown, M., & Robinson, P. (2003, November). The escritoire: remote collaboration in a task space. In *Proceedings of the 2003 acm sigmm workshop on experiential telepresence* (pp. 73-75).

[2] Bangor, A., Kortum, P.T., & Miller, J.T. (2009). Determining what individual SUS scores mean: adding an adjective rating scale. *Journal of Usability Studies archive, 4*, 114-123.

[3] Brooke, J. (1986). System usability scale (SUS): a quick-and-dirty method of system evaluation user informationReading, UK: Digital Equipment Co Ltd, 43, 1–7.

[4] Brooke, J. (2013). SUS: a retrospective. *Journal of usability studies*, *8*(2), 29-40.

[5] Cooper, A., Reimann, R., Cronin, D., & Noessel, C. (2014). About face: the essentials of interaction design. John Wiley & Sons. pp. 249-250

[6] Cornelius, C. J., Nguyen, M. A., Hayes, C. C., & Makena, R. (2012). Supporting virtual collaboration in spatial design tasks: Are surrogate or natural gestures more effective?. *IEEE Transactions on Human-Machine Systems*, *43*(1), 92-101.

[7] Czikszentmihalyi, M. (1990). Flow: The psychology of optimal experience. New York: Harper & Row.

[8] Ellis, C. A., Gibbs, S. J., & Rein, G. (1991). Groupware: some issues and experiences. Communications of the ACM, 34(1), 39-58.

[9] Fussell, S. R., Setlock, L. D., Yang, J., Ou, J., Mauer, E., & Kramer, A. D. (2004). Gestures over video streams to support remote collaboration on physical tasks. *Human-Computer Interaction*, *19*(3), 273-309.

[10] Gutwin, C., & Greenberg, S. (2002). A descriptive framework of workspace awareness for real-time groupware. Computer Supported Cooperative Work (CSCW), 11(3), 411-446.

[11] International Organization for Standardization. (2016). Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts (ISO/DIS Standard No. 9241-11:2018(en)). Retrieved from https://www.iso.org/obp/ui/#iso:std:iso:9241:-11:ed-2:v1:en

[12] Ishii, H., & Kobayashi, M. (1992, June). Clearboard: A seamless medium for shared drawing and conversation with eye contact. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 525-532).

[13] Johnson-Lenz, P., & Johnson-Lenz, T. (1998). Groupware: coining and defining it. ACM SIGGROUP Bulletin, 19(2), 34.

[14] Junuzovic, S., Inkpen, K., Blank, T., & Gupta, A. (2012, May). IllumiShare: sharing any surface. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*(pp. 1919-1928).

[15] Kirk, D., Rodden, T., & Fraser, D. S. (2007, April). Turn it this way: grounding collaborative action with remote gestures. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems* (pp. 1039-1048).

[16] Krueger, M. W. (1993). Environmental technology: Making the real world virtual. *Communications of the ACM*, *36*(7), 36-37.

[17] Odenwald, J., Bertel, S., & Echtler, F. (2020, June). Tabletop teleporter: evaluating the immersiveness of remote board gaming. In *Proceedings of the 9TH ACM International Symposium on Pervasive Displays* (pp. 79-86).

[18] *Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative research in psychology, 3(2), 77-101.*

[19] Tang, A., Neustaedter, C., & Greenberg, S. (2007). Videoarms: embodiments for mixed presence groupware. In *People and Computers XX—Engage* (pp. 85-102). Springer, London.

[20] Tang, J. C., & Minneman, S. L. (1991). VideoDraw: a video interface for collaborative drawing. *ACM Transactions on Information Systems (TOIS)*, *9*(2), 170-184.

[21] Unver, B., McRoberts, S. A., Rubya, S., Ma, H., Zhang, Z., & Yarosh, S. (2016, May). ShareTable application for HP sprout. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (pp. 3784-3787).

[22] Weiser, M. (1994). The World is Not a DesktopInteractions, 1(1), 7–8.

[23] Wilson, A. D., & Robbins, D. C. (2007). Playtogether: Playing games across multiple interactive tabletops. *Tangible Play*, 13.

[24] Yarosh, S., Cuzzort, S., Müller, H., & Abowd, G. D. (2009, June). C. In *Proceedings of the 8th international Conference on interaction Design and Children* (pp. 97-105).

[25] Yarosh, S., Tang, A., Mokashi, S., & Abowd, G. D. (2013, February). "almost touching" parent-child remote communication using the sharetable system. In *Proceedings of the 2013 conference on Computer supported cooperative work* (pp. 181-192).

## APPENDIX

### INTERVIEW QUESTIONS

[English] Do you have any initial thoughts on the system or on your experience?
[Swedish] Har ni några initiala tankar kring systemet eller av er upplevelse?

[English] You answered _ in the SUS-survey. Could you elaborate on why you answered the way you did?
[Swedish] Du svarade _ i det första frågeformuläret. Kan du utveckla ditt svar om varför du svarade som du gjorde?

[English] You answered _ in the extended SUS-survey. Could you elaborate on why you answered the way you did?
[Swedish] Du svarade _ i det andra frågeformuläret. Kan du utveckla ditt svar om varför du svarade som du gjorde?

[English] Did you notice high latency or lagging during the user study?
[Swedish] Upplevde du långsam uppkoppling eller hackande under användarstudien?

[English] Did you look at the video call on the laptop during the user study?
[Swedish] Tittade du på videosamtalet på datorn under användarstudien?

[English] How would you rank the importance of the voice call, the laptop's video feed and the shared table for the communication?
[Swedish] Hur skulle du ranka vikten av röstsamtalet, videon på datorn och det delade bordet för kommunikationen?

[English] What is your thoughts on the video call on the laptop? Did you find it redundant?
[Swedish] Vad tyckte du om videosamtalet på datorn? Tycker du det var överflödigt?

[English] What do you consider be the most positive feature of the system?
[Swedish] Vad anser du vara det mest positiva egenskaperna med systemet?

[English] What do you consider be the most negative feature of the system?
[Swedish] Vad anser du vara det mest negativa egenskaperna med systemet?

[English] Could you see yourself use this in a real-world situation, and if so, when?
[Swedish] Kan du se dig själv använda systemet i en mer reell situation, och i så fall, när?

[English] What do you think about video calls?
[Swedish] Vad tycker du om videosamtal?

[English] How did it feel to use the system?
[Swedish] Hut kändes det att använda system?

[English] In what situations would you see the system being used?
[Swedish] I vilka situationer ser du att system skulle kunna användas?