UPSTAIRS
A CALM AUDITORY COMMUNICATION AND PRESENCE SYSTEM

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ABSTRACT

For decades, researchers have been creating and evaluating so-called *media spaces*. Most of those were virtual spaces that bridge physical distance in order to create a common shared space. In the tradition of these spaces, *upstairs* supports peripheral awareness between non-colocated spaces but follows a different approach. Instead of creating a large unifying space, it makes use of the metaphor of wall-diffused noises commonly known from neighbors living upstairs or next door. When sharing a space, people are subconsciously aware of other people's activities, mainly because of their interaction with the environment. We designed *upstairs* to extend today's telepresence and social presence systems (i. e. most notably the telephone and videoconferencing solutions) that mostly focus on the transmission of the conscious part of communication and thereby enrich these systems by supporting peripheral awareness to allow for a permanent connection without distracting too much. In this paper we present the design decisions that led to realized system, the technical setup and the study we conducted over a two week time frame in the homes of couples in long distance relationships.

1. INTRODUCTION

With *upstairs* we introduce a calm [1, 2] communication system for couples in long distance relationships or, generally, people who like to feel close to one another. It was inspired by the observation that noises that diffuse through walls, e. g. coming from the upstairs neighbors, can give long-term insights into these people's behavior and emotions. When sharing a space, we are subconsciously aware of other people's activities, mainly because of their interaction with the environment. This awareness can be recognized as a socially organized and contingent achievement which is often bound to artifacts in the users' environment. We built *upstairs* to study if a subconscious level of awareness and communication can be sustained while the interactants live at two remote places. Based on communication theory, such a system should consist of at least two parts for each space: a capturing device and a display for peripheral use, meaning that it is "out of a person's primary focus of attention." Interpersonal interaction consists of many information cues that the interactants most often process in parallel. Roughly, these streams can be discerned into being either consciously (e. g. speech, sign language) or more implicitly used (e. g. prosody, facial expressions, proxemics). While the conscious part of a conversation might stop at some point, implicit streams remain indefinitely as long as people share a space. In other words, even when people don't talk to each other, there is still communication going on.

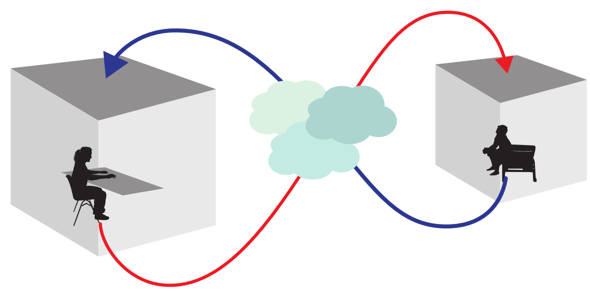

Figure 1: Schema of two rooms being connected via *upstairs*.

When living in close physical proximity, for example in the same apartment, people still perceive cues about the daily lives of other people through walls and ceilings. People also like to modify the amount and quality of cues they share with other people, for example by opening or closing a door. What *upstairs* does is to simulate a ceiling that connects two rooms as if they were adjacent when they are actually not. Because the connection is purely virtual, it not only works regardless of physical distance but can also be much more finely adjusted than a physical connection can be.

There has been extensive research in the field of media spaces where the goal was to connect two remote spaces as if they were one single space [3, 4, 5]. Unobtrusiveness was paid little attention to, though. Maybe for this reason, there was also little notion of not only connecting spaces with technical means but also *separating* them at the same time. Another relevant area of research is what is called *awareness systems* [6]. These systems share the goal of creating a calm connection that can also be persistent and therefore *upstairs* can be seen as one such awareness system.

As illustrated roughly in Figure 1 and more detailedly in Figure 2, *upstairs* connects two rooms by virtually stacking them mutually atop each other. It will appear to Person A as if Person B lived upstairs and vice versa.[1]

Even though awareness systems share much of the same goals,

[1]Note that the sound is always coming from above – and *not* from above for one user and from below for the other as would be the case with the real

no other systems that quite align with our design goals (cf. Section 2) have come to our attention yet. We previously built a presence system using smartphones that transmit movement as vibration called FEELABUZZ [7] which was desigend along similar aspects, but the approach did not achieve the desiresd calmness [8].

2. DESIGN ASPECTS

For the development of *upstairs*, the Blended Sonification guidelines [9] for auditory interfaces were followed with a focus on:

a) calmness and peripheralness

b) expectability and familiarity

Briefly, *calmness and peripheralness* connotes that the interface should be placed in the ambiance of the user without distracting too much. People are able to 'background' large parts of the complex soundscape they are surrounded by. When these environmental soundscapes are used as a canvas we can benefit from that fact. If a user wants to selectively pay attention to something, it is available at an instant with no further effort; if not, it stays out of the way. It is possible to use such qualities of environmental soundscapes in artificial scenarios, for example by means of auditory augmentation [10].

Additionally, when the information changes – which in this case are the others user's actions – and thereby the auditory representation, it can catch the user's attention before returning to the usual background noise. The sound stream should blend into the environment and should be perceivable as coming from above, i. e. upstairs. In general, the resulting auditory response should be *expectable* by the users. It should stay within the bounds of being *familiar* as much as possible. Hearing the sounds from a neighbor above is an experience that many have made before and is therefore well suited for this kind of display because it builds on prior experiences. The interface thereby creates some kind of illusion.

In accordance with these guidelines we tried to stay as close to the original sound signal as possible. No arbitrary sounds were added. The sound was just filtered to match a familiar metaphor of walking or action sounds from a person who lives upstairs.

3. HARDWARE SETUP

On a technological level, we used contact microphones on the floor that only capture the vibration of the floor itself but not of the air in the room. That signal is then filtered, transmitted over the network and played back over speakers close to and directed at the ceiling to give the illusion of the sound coming from the room above.

We experimented with different kinds of floors and flooring materials. Hard concrete or stone floor, soft vinyl flooring and the very flexible and elastic floor of a shipping container office transmitted footsteps very poorly: footsteps could only be heard up to 40 cm away from the microphone for concrete and even less for the elastic floor. Carpeting, even thin one, even worsened the situation considerably. We found wooden floor to work best; the only real loss of energy seemed to occur at plank boundaries. Laminate flooring also worked quite satisfactory. All in all, we observed that the perceived loudness of the footsteps in the room itself is not a measure for the amount of acoustic energy that is transmitted to and by the floor.

physical analog of two actual rooms one atop the other.

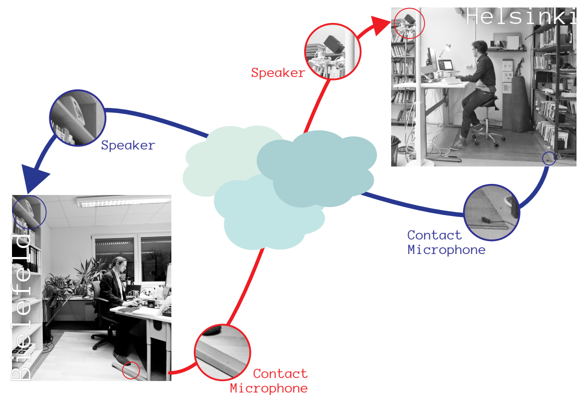

Figure 2: Setup connecting two offices in Helsinki and Bielefeld.

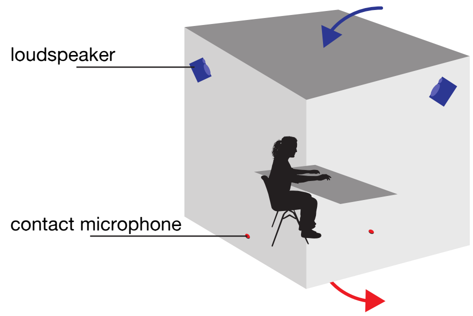

Figure 3: Local *upstairs* setup.

Common means to insulate against noise transmission to adjacent rooms have little effect on the walking noise within the room [11] or on the effectiveness of our sound recordings with contact microphones. In fact, when we used a sheet of felt between the laminate and the concrete floor beneath it, even soft movements without shoes became audible and sounded surprisingly natural.

To capture the contact sound, capacitive AKG C411 contact microphones were used[2] because of their qualities in both capturing performance – especially a low signal-to-noise ratio – and physical robustness.

We experimented with variations in the number of microphones for stereo or multichannel sound but found that in all our more conventional setups, no perceivable spatial resolution was achieved. Only a setup in a very large hallway was able to deliver convincing spatial audio. There, the two microphones were spaced over 3 m apart in an even larger room, allowing movement beyond the stereo base.[3]

To create the illusion of sound traveling through floor and ceiling, we used a band-pass filter (more specifically the combination of a second-order Butterworth low-pass and high-pass filters) with

[2] http://www.akg.com/pro/p/c411group

[3] Recordings from this stereo setup can be found at https://soundcloud.com/lfsaw/sets/test-recordings-for-the-shared.

cut-off frequencies at 50 Hz and above 300 Hz. Filtering was done using the SuperCollider language.[4]

As the type of loudspeakers plays an important role for the perceived sound due to the two factors frequency response and radiating properties, we adapted filter parameters accordingly. By facing the speakers upwards, the sound was distributed towards the ceiling so that the first reflections are heard most prominently. The resulting large emitting angle helped to increase the illusion of the whole ceiling giving off the sound. The wider the emitting angle of the speakers to begin with, though, the better the overall result that was achievable.

4. USER STUDY

4.1. Method

We conducted a small-scale study in order to get a first indication regarding the effect of *upstairs* on couples in long-distance romantic relationships (LDRRs) and to collect some user experience from people using our system over a longer period of time.

We evaluated *upstairs* by giving two connected setups to couples living in an LDRR who installed the systems in their homes. There were three couples, making for $n = 6$ participants in total. Each couple was supposed to use the system for two weeks but in one of the couples, one partner moved to a new apartment without the necessary wooden or laminate floor before this two-week period could be finished.

Participants were asked to complete one questionnaire before starting to use the system and one afterwards.

The participants were all heterosexual couples and two of the three were married. The participants were between 29 and 35 years old ($\bar{x} = 31.3$ a, $SD = 2.1$ a, $Md = 31$ a). The length of their relationships ranged between 5.3 and 12.8 years ($\bar{x} = 9.2$ a, $SD = 3.4$ a, $Md = 9.5$ a) while the part of the relationship that they themselves considered to be an LDRR[5] varied between 41 days and 3.5 years ($\bar{x} = 1.7$ a, $SD = 1.4$ a, $Md = 1.8$ a). These self-reports were not exactly the same between partners but reasonably close (with an average standard deviation of 26 days and an average coefficient of variation[6] of .04). Regarding the separation-reunion cycle [12] at the time of the study, all participants said to meet their respective partner two to three times a month. Participants were also asked for their experience with computers and how much they would consider themselves to have a disposition for technology. All participants rated themselves within the two response options signifying the most experience and disposition for technology on a 7-point scale.[7]

Additionally to completing a questionnaire before and at the end of the usage period, an unstructured interview was held with each participant to also get subjective feedback, reflecting the exploratory stage of this research. The questionnaires were adapted from a number of sources [13, 14, 15, 16, 17, 18, 19, 20, 21]; most prominently from the Affective Benefits and Costs of Communication Technologies Questionnaire (Adult ABCCT) by [15] which itself uses many sources but is mainly based on the very similarly named Affective Benefits and Costs of Communication Questionnaire (ABC-Q) by [16] and the social connectedness questionnaire also derived from the ABC-Q [17].

The questionnaires were anonymized with code names to avoid impersonal and easy to forget numbers and implicitly encode gender and pairing information through the use of famous movie couples.

The last couple were also given the opportunity to use the system longer than we asked them to do. This was part of the evaluation without the participants knowing this. We wanted to find out if the participants used *upstairs* only because we asked them to or if they liked the system so much that they used it for as long as they could. We deemed this a more reliable method to assess the motivation of the participants than asking them whether they liked using the system or if they would use it if they had the opportunity to do so (which we also did). Unfortunately, the schedule did not allow for the other couples to be given this opportunity unsuspectingly.

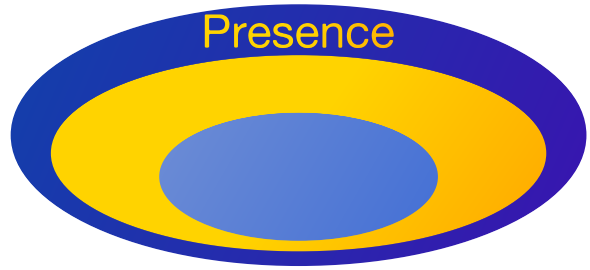

Figure 4: Euler diagram of the relation between presence (a.k.a. telepresence), copresence and social presence.

4.2. Hypotheses

We expect *upstairs* to create an aspect of telepresence called *copresence* [22, 8] while not creating the more conscious *social presence* [23, 14, 8] and more generally *cognitive load*. The reason is that we want the system to enable a permanent connection and distractions should therefore be minimized.

We used copresence and social presence scales assembled from other authors while developing a new cognitive load scale (cf. [8] for details).

We therefore expect *upstairs* to induce a high amount of copresence while maintaining a lower level of social presence. Accordingly, cognitive load should be low and people should find it convenient to have the system running continuously. Ideally, the effects of the system should occur without the participants even immediately noticing them or at least without them being distracted from other activities.

Among all the scales present on the questionnaires, some of which we will look at in the following section, we especially hope to find a low Cognitive Load and a low Threat to Privacy since this would correspond with our design goals.

However, it should be noted that the study has a very small sample sizes, especially compared with the complexity of the questions raised and the tentativeness of the results can therefore not be overemphasized. Because of this, the evaluation will be in large parts exploratory and hypotheses-generating in nature.

[4] `https://supercollider.github.io/`

[5] [12] proposed to prefer such subjective self-reports over objective but arbitrary criteria in order to determine whether a relationship is long distant. As for objective measures, the participants lived between about 250 km and 760 km driving distance apart.

[6] The coefficient of variation is the standard deviation normalized by the mean, i. e. $CV = \frac{\sigma}{\mu}$.

[7] We actually required the non-local participants to have at least some technical background because setting up the prototype was not trivial.

Still, putting the expectations from the previous section more formally, these are the hypotheses we want to test:

(H1) Copresence ratings are better than Social Presence ratings.

(H2) Cognitive Load is lower than the scale center.

(H3) The perceived Threat to Privacy is lower than the scale center.

(H4) The measure of Copresence is better than the scale center.

4.3. Results

In the following we will highlight important aspects of the results. An overview of the complete set of scales used is also shown in Figure 5. A more detailed evaluation of the study can be found in [8].

Because evaluating such low-level channels as *upstairs* is non-obvious, part of the following evaluation will be concerned with the scales themselves and how scales from different authors measuring similar concepts play together.

4.3.1. Hypothesis Testing

The Overall Copresence ($\bar{x} = 3.26$, $SD = .59$) is significantly higher than the Overall Social Presence ($\bar{x} = 4.04$, $SD = .99$); paired one-tailed $t(5) = -3.32$, $p = .011$. Cohen's d indicates a large effect size ($d = -.96$ [24]) [24]. This confirms (H1) and the non-parametric Wilcoxon signed rank test corroborates this result, $Z = -1.99$, $p = .023$. Low values on these scales always signify a high presence.

The Cognitive Load self-reports ($\bar{x} = 3.38$, $SD = .33$, low values mean a low cognitive load) are significantly lower than the scale center of $\mu = 4$, paired one-tailed $t(5) = -2.68$, $p = .022$ with a large effect size ($d = -1.69$), confirming (H2) ($Z = -2.00$, $p = .023$).

The perceived Threat to Privacy ($\bar{x} = 2.13$, $SD = 1.35$, low values mean a low perceived threat) is also significantly lower than the scale center, paired one-tailed $t(5) = -3.93$, $p = .006$ with a large effect size ($d = -2.48$), confirming (H3) ($Z = -2.20$, $p = .014$).

Overall Copresence is also significantly higher than the scale center, paired one-tailed $t(5) = -2.36$, $p = .032$ with a large effect size ($d = -1.49$), confirming (H4) ($Z = -1.78$, $p = .038$).

4.3.2. Copresence

All Copresence scales yielded similar and moderately good results (Isolation/Aloneness: $\bar{x} = 3.67$, $Md = 3$; Mutual Awareness: $\bar{x} = 3.56$, $Md = 3.5$; Perceived Other's Copresence: $\bar{x} = 2.83$, $Md = 3$) that were significantly better than the scale center when put together (cf. (H4) in Section 4.2). Combining the Perceived Other's Copresence [20] and the two Copresence scales from the Networked Minds Questionnaire [13] into one scale reveals that these scales seem to measure the same construct (combined $\alpha = .89$) which is not surprising since – other than the name might imply – the Perceived Other's Copresence scale is *not* mainly about gauging the partner's state of copresence feelings. The two Networked Minds scales[8] also work nicely together, ($\bar{x} = 3.58$, $Md = 3$, $\alpha = .85$).

The participants indicated that *upstairs* managed to create a common space between the two remote locations ("I often got the feeling of sharing a space with my partner." $CI_{.95} = [1.98, 3.69]$, $Md = 2.5$),[9] even though participants did not forget that the two locations were actually separate ("I was often aware that my partner and I were at different places." $CI_{.95} = [2.31, 4.02]$, $Md = 3$).

[8] Isolation/Aloneness and Mutual Awareness; referring to the Networked Minds Questionnaire [25, 13, 26]

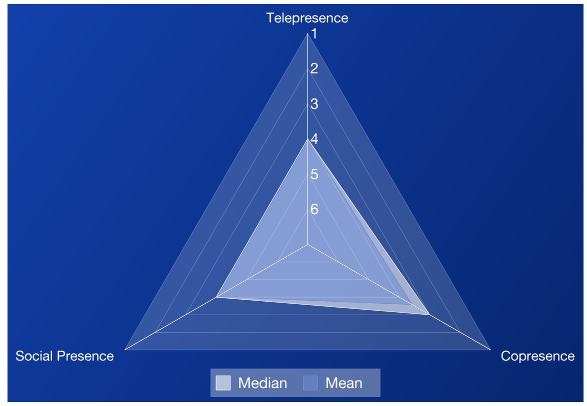

Figure 6: Excerpt from Figure 5 showing only the Telepresence, Overall Copresence and Overall Social Presence Scales.

4.3.3. Social Presence

There are two scales for social presence, both from [14]. One uses direct questions, the other the semantic differential technique developed by [27].

Generally, the social presence indicators are relatively low as we had hypothesized, at least on the scale using direct questions ($\bar{x} = 4.75$, $Md = 5$, $SD = 5.03$). On the scale using the semantic differential technique, however, this is not the case ($\bar{x} = 3.47$, $Md = 3$, $SD = 3.73$; cf. Figure 5). Both scales feature a similarly good Cronbach's $\alpha > .8$ and their combined α is .88 whereas their correlation is only $r(4) = .57$, $p = .237$. However, if the different means (paired two-tailed $t(5) = 2.94$, $p = .032$) and the mediocre correlation should mean that the two scales measure two different constructs, the item-total correlations and a PCA do not support this view (cf. [8]).

The system failed to transmit the moods from one participant to the other as shown by the combined Emotion Transmission scale ($\bar{x} = 5.17$, $Md = 5.5$) and in particular by items such as "I was influenced by my partner's moods" ($CI_{.95} = [3.87, 6.13]$, $Md = 5$). This point was further confirmed by all participants in the interviews. Participants felt that there simply was not enough information about the emotional state of the other in the signal and could not imagine there to be such information with the exception of extreme rage.

4.3.4. Telepresence

Telepresence, as used in this work, is a concept that is even more general than copresence and does not necessitate any interpersonal relationship. For a hierarchy of presence concepts cf. Figure 4.

The Telepresence scale ($\bar{x} = 4.03$, $Md = 4$) seems semantically related to the Mutual Awareness scale ($\bar{x} = 3.56$, $Md =$

[9] $CI_{.95} = [x, y]$ means that the 95 % confidence interval ranges from x to y.

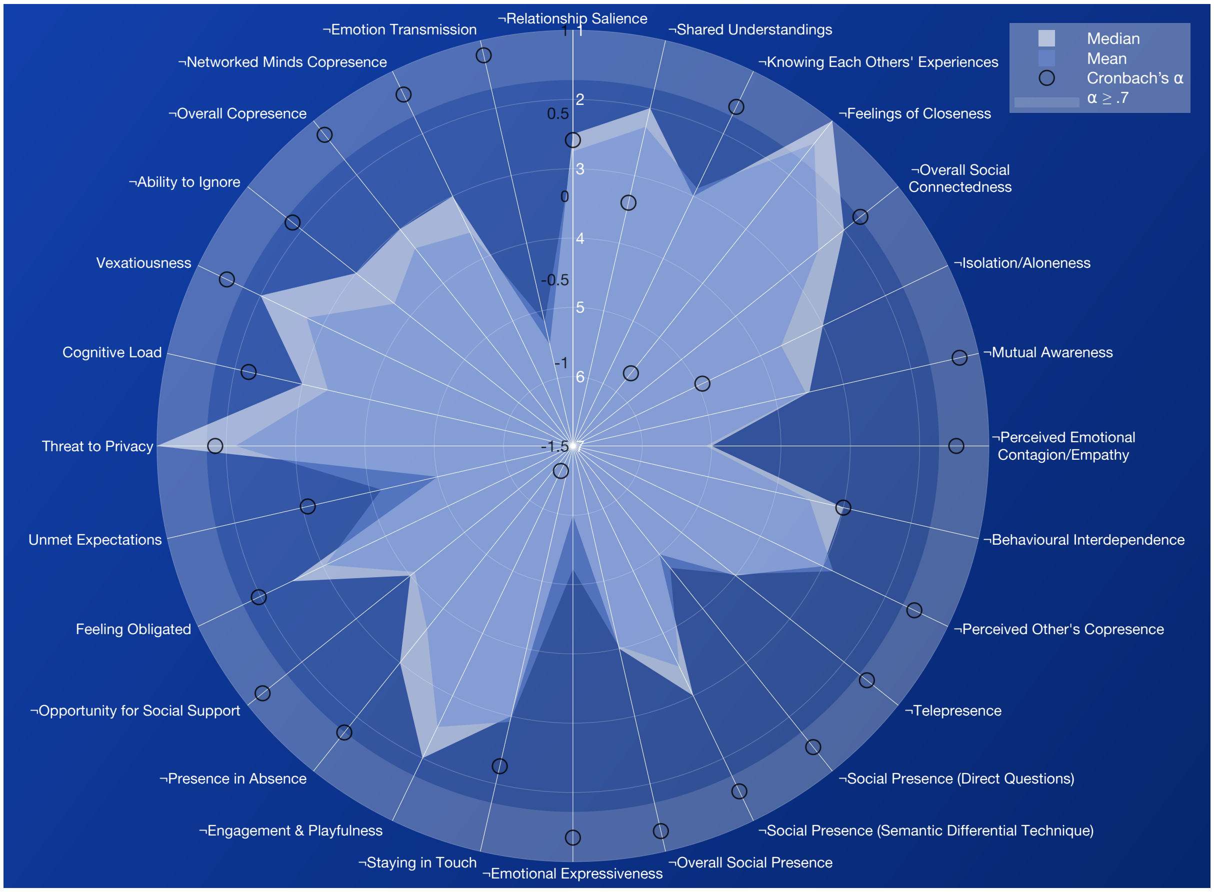

Figure 5: Overview of results for all scales of the final questionnaire. A larger area (smaller numeric value) means a "better" result and scales that were therefore inverted in their meaning are marked by "¬".

3.5). The correlation between the two is strong even though only marginally significant $r(4) = .75$, $p = .083$ and they have a common $\alpha = .90$. There are two items in each scale that do not fit with the rest but otherwise the two scales are virtually indistinguishable. The Perceived Other's Copresence scale shows no such obvious semantic similarities (but a similar correlation $r(4) = .81$, $p = .053$, common $\alpha = .86$).

4.3.5. Cognitive Load

The result of a low cognitive load (Cognitive Load: $\bar{x} = 3.38$, $Md = 3$; cf. Figure 5 and (H2) in Section 4.2) was also strongly emphasized in the interviews. Most participants said that they were aware of the sounds but they did not bother them in any way. One couple said that they often did not consciously perceive the sounds and described them as being part of the background. One participant described how he often only became aware of the system's output when the sounds had stopped because his partner had gone to bed. Many participants commented on the presence of unwanted noises such as blips and static and described these as the most annoying part of the system, even though none said to have been more than mildly annoyed. One participant heard a constant low buzzing noise which was the most annoying sound reported by any participant. See Table 1 for a quantitative assessment of these issues. The intended sounds transmitted by the system were unanimously described as pleasant. It is therefore our impression after the interviews that the cognitive load could have been even better if the sound output had been free from digital or analogue artifacts.

4.3.6. Privacy

Since privacy was a concern that we ourselves had, it is good to see that this was not perceived to be much of an issue, with the Threat to Privacy being rated significantly lower than the scale center ($\bar{x} = 2.13$, $Md = 1$; cf. (H3) in Section 4.2).

The only concern mentioned during the interviews was that a third party might gain knowledge over when the participants are not at home. Other concerns were not mentioned and most participants explicitly said that they were not worried to inadvertently disclose anything to their partner over the system. This is also strongly expressed in the questionnaire item "I worried that my partner might learn something using the system that I want to keep secret", $CI_{.95} = [6.07, 7.26]$, $Md = 7$. Some also mentioned, though, that

Kind of Noise	Number of Users Affected
Static (*Rauschen*)	4
Interruptions	3
Blips/Artifacts	3
Phantom Steps	0
Laptop Fan	1
Speech	1
Mobile Phone Interference	1

Table 1: Kind and frequency of noise reports for *upstairs*. Only reports in the questionnaires are counted (either from the multiple choice or the free answers – the latter are all entries below "Phantom Steps"). Cf. Table 2 for intentional sounds that were transmitted. Speech was heard by all participants but only put down once on a questionnaire. A buzzing noise was mentioned in one of the interviews but not put on a questionnaire.

this might be different with people that they were not as close to as their partner.

4.3.7. Emotional Value

All participants reported at least some moments in which *upstairs* created a feeling of closeness and attachment towards the partner. For most, this feeling was a constant sentiment throughout using *upstairs* while for some it was confined to such singular moments. Many participants reported feelings of sadness or sentimentality during the dismantling of their system or a feeling of loss afterwards.

Although *upstairs* managed to play this emotional role for many participants, as briefly mentioned in Section 4.3.3, the system apparently failed to transmit emotions or moods experienced by the remote partners themselves. This can be seen from the bad values on the highly correlated ($r(4) = .85$, $p = .033$, common $\alpha = .91$) Emotional Expressiveness ($\bar{x} = 5.22$, $Md = 6$) and Perceived Emotional Contagion/Empathy ($\bar{x} = 5.08$, $Md = 5$) scales (Figure 5) and also from unanimous reports during the interviews. Few participants saw any potential for such transmissions, no matter what quality improvements would be made or how much time users had to get used to the signals.

The reports from the questionnaires about the expectations towards the partner regarding *upstairs* are a mixed bag; on the one hand there are items like "I was disappointed when my partner wasn't there when I tried to contact him/her using the system" ($CI_{.95} = [1.86, 3.80]$, $Md = 3$) and "I was disappointed when it took my partner too long to respond over the system" ($CI_{.95} = [1.76, 3.91]$, $Md = 2.5$) from the Unmet Expectations scale ($\bar{x} = 4.17$, $Md = 5$),[10] indicating that there is a certain emotional investment in the system. On the other hand, "I worried that my partner felt obligated to contact me using the system" ($CI_{.95} = [4.49, 6.51]$, $Md = 6$) and "I felt guilty if I didn't respond to my partner when I perceived something using the system" ($CI_{.95} = [4.66, 7.00]$, $Md = 6.5$) from Feeling Obligated ($\bar{x} = 3.04$, $Md = 2.5$) seem to say that the participants did not act on that emotional investment (cf. Figure 5). Similarly, some participants reported in the interviews that they felt sad or disappointed when they used knocking as a direct way of communicating through the system and their partner did not answer.

Depending on the interpretation, this emotional investment need not be an entirely bad thing, even if it means that users are disappointed when their partner is not there or otherwise does not react. Seen within the greater context of technology dependence, the new channel becomes just another of those pieces of technology that we develop some level of dependence on, exactly *because* they are useful.

[10] As a sidenote, the Unmet Expectations scale gets a dramatically increased $\alpha = .66$ (new $\bar{x} = 5.17$, $Md = 5$) if the poorly worded "I worried that I was not meeting my partner's expectations for our contact using the system" is left out (original $\alpha = .13$).

Kind of Sound	Number of Mentions
Footsteps	6
Knocking	6
Door Sounds	1
Chair Movement	3
Other Impact Sounds with Floor	2
Rustling	1
Impact Sounds with Furniture	1
Window Blind	1
Speech (unintelligible)	6
Speech (intelligible)	0
Misc Non-Structure-Borne	2

Table 2: Types of sounds transmitted by *upstairs* as reported by the participants in the interviews. All mentions were spontaneous, therefore the true numbers may be higher if the participants forgot to mention a certain type of sound. Multiple mentions by one participant were only counted once. Noise not transmitted but created by the system itself is not covered here but in Table 1.

4.4. Discussion

While it has to be stressed again that the results above are to be taken with an appropriately sized grain of salt due to the small-scale nature of the study, it is cause for optimism that our hypotheses were confirmed, meaning that copresence was reasonably high and higher than social presence, while at the same time the the cognitive load and the perceived threat to privacy were rated low.

The lack of a measurable distinction between presence and copresence poses the interesting question if there is a clear difference between these concepts for systems such as *upstairs*. It would stand to reason that for systems that try to create the presence of a remote partner, the presence *in* a common space *with* the remote partner and the presence *of* the remote partner might be one and the same thing. This would be because, as opposed to virtual environments, with systems like *upstairs* there is no sense of space other than what is transmitted from the remote partner. This would also be in accordance with the findings of [28, 29], whose correlation between telepresence and copresence went away when immersion decreased.

Some of the more mundane problems with the usefulness of *upstairs* that were mentioned during the interviews were the need to wear shoes,[11] having the wrong flooring,[12] and obviously the

[11] As indicated earlier, a possible way to overcome this obstacle would be to pad the flooring with felt, enabling even sneaking on socks to be heard. This is quite intrusive of course so we did not require or even suggest this in our study.

[12] We required all participants to have wooden or laminate flooring but one

problem of not producing any sounds when not moving, especially for extended periods of time.

All participants used explicit communication in addition to the implicit context communication the system provides anyway. The participants used simple knocking patterns (e. g. three times in a row) and no more than two semantically distinct patterns were used (for greeting and parting). One couple had thought about using Morse code but ended up not doing it, saying that there were better ways to communicate verbally than *upstairs*. Another couple developed the knocking into a ritual that they would perform each time one of the partners came home.

Most participants said they did not have the impression that *upstairs* changed their communication behavior using other media with the notable exception of letting them know when their partner was home so that it was worthwhile to call by phone.

All participants said that they would have used the system for longer if they had been given the chance. The last couple who actually had that chance continued using *upstairs* for several weeks and only stopped doing so when one of the partners had a favorable opportunity to personally bring the hardware back to us and used this opportunity.

One participant said that he would not want to use such a system indefinitely because he liked being alone from time to time and with such a system he would never feel really alone.

The normal *modus operandi* of *upstairs* as a system that was constantly running was very much appreciated. One participant kept the system running even when leaving home for the weekend. It was also emphasized that not having to adjust any system parameters after the initial setup except for adjusting the volume from time to time was very important. Nobody reported to have used the possibility of self-monitoring after the initial setup phase.

The importance of directness was also often highlighted. The knowledge that it was actually their partner whom they heard was deemed important and when confronted with ideas of more abstract, mediated or persistently direct systems (such as presence lamps [30, 31] or footstep recognition [32]), participants rejected them as much less appealing.

As many participants used *upstairs* in the room they also slept in, this was a recurring topic. One participant liked lying in bed in the morning, hearing that her partner had already gotten up and also found this a good motivation to get up herself. Two participants found it comforting to hear their partners still being awake when falling asleep themselves and one of them mentioned that she felt like not going to bed alone when hearing her partner. Another mentioned a sense of safety conveyed through the sounds of her partner. One participant simply found it useful to hear when his partner had already gone to bed so he could call her late without risking to wake her.

Finally, it is good to see that the system seemed to be enjoyable. Even though the Engagement & Playfulness scale itself has an outright abysmal internal consistency ($\alpha = -1.33$), its overall value is quite good ($\bar{x} = 2.50$, $Md = 2$) and there are encouraging items like "I was excited about using the system with my partner" ($CI_{.95} = [2.35, 3.65]$, $Md = 3$), "I had fun with my partner using the system" ($CI_{.95} = [1.29, 2.04]$, $Md = 2$), and "I liked using the system"[13] ($CI_{.95} = [1.54, 2.46]$, $Md = 2$).

In the interviews, using the system was described as "comforting", "fun", "enjoyable", "entertaining", "pleasant", conveying a "warm feeling" and as an opportunity to be closer to the partner without having to actively do something.

participant had different flooring in other rooms and therefore effectively went silent upon leaving the room.

[13]not part of the Engagement & Playfulness scale

4.4.1. Discussing the Acoustic Modality

The importance of the non-visual channel was emphasized unanimously by the participants, as a visual signal was thought to be distracting or less persistent and easily forgotten. Being asked if they could imagine using a visual analogue to *upstairs*, participants dismissed the idea and said that not having to look somewhere to monitor the signal was crucial.

In the interviews, participants described the sounds transmitted by the system as pleasant. One participant said she needed two days to get used to this new sound source because she at first confused the sounds with real neighbors or animals in the walls. Most participants did not think that *upstairs* sounded like real upstairs neighbors but this was not seen as negative. Some participants even said that they found the quality of the transmission more pleasant than that of a real ceiling as it was less muffled and more crisp while still being dampened enough as to not be distracting. During the interviews, "fitting", "right" and "natural" were words used to describe how the footsteps sounded. One participant called the sounds "80 % authentic."

Table 2 summarizes the types of noises participants perceived via *upstairs*. As shown in Table 1 and mentioned in Section 4.3.5, unwanted noises produced by the system itself were mentioned by all participants with varying impressions on how annoying they were perceived to be. For most of the participants, though, solving the problems causing these acoustic artifacts was a prerequisite for a hypothetical prolonged use of the system.

When asked to speculate on the effect of a system that simulated footsteps *within* the same living space as opposed to the spatially separated one *upstairs* provided, some participants felt that our worries that this might be a creepy "poltergeist" kind of effect were plausible but none came up with such worries by themselves.

5. CONCLUSION

We built a system called *upstairs* that connects two non-colocated people by making them mutual virtual upstairs neighbors through the use of contact microphones and speakers directed towards the ceiling. The goal was to create a permanent connection that mediates a sense of copresence without the users having to actively communicate or the system distracting them from other tasks or their daily lives in general.

Even despite the limited sample sizes of the study we conducted, we feel cautiously confident to say that it showed that such permanent, synchronous, low-bandwidth channels can be applied successfully in a personal and home environment without inflicting a high amount of cognitive load, a result that is complementary to the design process by Hindus et al. [31] who moved away from synchronous to asynchronous channels. They also found implicit presence information not to be well-received by their focus group. With *upstairs* we showed that people can accept implicit presence signals. From the interviews and the free answers, we suggest that such systems should be calm and make use of familiar metaphors as well as function in an expectable way. We have some evidence that copresence and telepresence are no distinct concepts in the context of copresence systems, while copresence and social presence behave the way we had hoped, with copresence being higher than social presence and them not showing a high correlation. Users of *upstairs* were extremely positive about its effect and all of them wished to continue using it and they were able to provide convincing examples of when the system had an emotional effect on them to make this claim believable. The one couple that actually had the opportunity to continue using the system did so unsolicitedly.

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