Hybrid Ludo: Combination of a Tangible UI for Seniors and a Web-based Ludo Game

Bernhard Wohlmacher[a], Fabian Mertl[b], Holger Klapperich[c] and Alina Huldtgren[d]
Hochschule Düsseldorf, Münsterstr. 156, 40476 Düsseldorf, Germany

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Abstract: During the ongoing pandemic, the need for senior-friendly remote communication systems became more than apparent. While communication could be switched with little effort from face-2-face to online video conferencing in many areas of life, these systems still provide barriers for a broad range of older people. In addition, the simple provision of a digital communication tool does not inherently provide opportunities for meaningful interactions and the creation of new memories. However, especially in times of (physical) contact limitations, it is not sufficient to do video telephony but also to engage in remote activities that are meaningful, playful, and lead to shared memories. We posit that a hybrid system offering tangible and web-based interactions, while each being adapted to the living situations of particular users (e.g. seniors and their younger relatives), can overcome the lack of meaningful engagement in existing video telephony systems. This paper provides a new interaction concept based on hybrid user interfaces and describes the development of a proof-of-concept prototype of a digital game of Ludo that comprises a senior-friendly tangible interface, a web-based interface, and an integrated video conferencing function.

1 INTRODUCTION

Loneliness is a central problem of old age (Armitage & Nellums, 2020; Brooks S K et al., 2020; Cudjoe & Kotwal, 2020) that intensified during the last two years of the Covid-19 pandemic. Already before the pandemic, old citizens, who were less mobile, lived in rural areas and/or had relatives living far away suffered from loneliness and relied on communication technologies, foremost the telephone, to stay in touch with their social network. They rarely used video telephony or social media to connect (Sacco et al., 2020), among other reasons due to fear of making a mistake or because they perceived technologies to be too complicated.

However, during the pandemic, loneliness increased exponentially due to additional limitations of physical contact. In our country, we experienced times of complete lockdown; visitors were not allowed into care homes, and only people from two households could meet at home. Whereas companies and universities quickly transitioned to home office or remote teaching settings, using collaboration and communication software including video telephony (e.g. Zoom, MS Teams), seniors coped less easily. Many seniors are not familiar with these tools or do not have access to computers or mobile devices (e.g. in care homes). Especially people with mild cognitive impairments or dementia have problems getting accustomed to digital technologies.

Furthermore, even if older adults connect to their relatives through communication technologies, conversational difficulties arise due to a lack of recent shared experiences to talk about (due to immobility or lockdown) as well as a lack of meaningful interactions with each other at the time of the call. Especially in intergenerational communication, e.g. between an older and younger relative or caregiver, conversational hurdles may include different living circumstances and foci as well as a lack of knowledge about the others' backgrounds. Some research has suggested providing so-called 'Tickets-to-Talk' to

[a] https://orcid.org/0000-0001-6069-5666
[b] https://orcid.org/0000-0002-6923-2526
[c] https://orcid.org/0000-0002-0321-6187
[d] https://orcid.org/0000-0002-0542-8626

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trigger intergenerational conversations in the context of dementia, providing young carers with an app (Welsh et al., 2018). "Ticket to Talk" provides inspiration in the form of generic suggestions, personalised with information from the older person's profile. These prompts typically invite the young person to find out a bit of information about the life history of the person they are creating tickets for, and to create media related to this. For example: "Steven was 18 in 1940, can you find a picture of London at that time?" (ibid, p.375). While this approach can lead to more meaningful conversations, it does not solve the problem of fostering significant interactions and creating new memories. In our view, video telephony is an important technology to connect humans, but it is only a means to an end. We need to create a meaningful social practice as a reason to feel connected, satisfying the psychological need for relatedness (Hassenzahl et al., 2012).

New concepts and systems are needed to allow for more meaningful engagement between remote people. For technology-savvy people, online gaming platforms or shared TV watching tools provide solutions to engage in a shared activity while remote. However, these tools are often not used by seniors who are not technology-savvy.

Thus, the central research question in our work is "How can we provide a system for intergenerational engagement over a distance?" Subquestions include "How can we allow seniors with little or no digital experience to engage with others remotely?" and "Through which activity can we trigger engaging, affective and meaningful interactions that provide memorable experiences?"

The goal of the work presented in this paper is to provide a novel approach to online communication and interactions by employing hybrid user interfaces in the context of traditional gameplay and a technical proof-of-concept in the form of a running prototype.

2 RELATED WORK

2.1 Closeness at a Distance and Wellbeing

In general, closeness at a distance is essential for humans because it can satisfy the psychological need for relatedness and thereby increase subjective wellbeing. Also, Ryan and Deci's Self Determination Theory identifies relatedness in addition to autonomy and competence as the primary needs motivating human behaviour (Ryan & Deci, 2000). Hassenzahl and colleagues (Hassenzahl et al., 2012) introduced technology-based concepts for partners in long-distance relationships, which enable closeness at a distance, but also create a social practice by inscribing the meaning of relatedness. For instance, the concept of awareness is based on devices (e.g. a digital picture frame), which show a moment with someone you feel related to. Another idea is to give a gift to a related person, which could be an individual recipe for a shared lunch, or to keep memories alive by collecting sounds of a shared moment. All those strategies could be used in a close relationship, but also over a distance. The authors argue, "besides the challenge to point out the benefits of alternative, less explicit forms of communication, we require more profound insights into people's acceptance and willingness to use such devices." (Hassenzahl et al., 2012, p.15).

2.2 HCI for Intergenerational Communication

In their literature review, Reis and colleagues (2021) identified that technology for intergenerational connectivity is an emerging field, while interventions are mainly game-focused. They argued for a more multidisciplinary approach to balance the lack of methods and consistent vocabulary. Moreover, they state that "[t]he increasingly ubiquitous and flexible nature of technology is enabling innovative and exciting approaches to connect youth and older adults in many ways" (Reis et al., 2021, p.17)

A central problem leading to conversational difficulties across generations is the generational gap that can form barriers and unfamiliarity with an older person's experiences (Powell & Arquitt, 1978). In a study about the use of information and communication technology (ICT) with focus-groups of young and old people, Pieri and Diamantinir found out that "[…] while elderly use the cell phone almost exclusively to make calls, young people make a more intensive use of it, since they also exchange text messages, use it as a personal agenda, listen to music, take pictures and so on. The relationship with the cell phone can become almost symbiotic" (Pieri & Diamantinir, 2010, p. 2424).

Especially for people with dementia, a condition affecting older people more often, digital communication technology is hard to approach due to cognitive impairments and difficulties to learn new things. Systems need to be designed to promote acceptance and enable the usage in an everyday context, not only for people with dementia but also for people who want to communicate with them.

The concept "Ticket-To-Talk" (Welsh et al., 2018) is an interesting example, which shows how

communication technology for intergenerational use could offer an occasion to talk. It suggests communication topics through a digital application, based on the life story of the person with dementia. By introducing individual bibliographic data, the person with dementia could easier remember the personal conversation topic, and the communication partner does not need to search for an appropriate subject.

2.3 Older People and (Digital) Gaming

Previous studies found that a higher frequency of gameplay in old age was associated with a higher cognitive function. Playing more games was also associated with less general cognitive decline from age 70 to 79, and particularly less decline in memory ability. Also, playing games frequently between 70 and 76 was associated with less decline in cognitive speed (Altschul & Deary, 2020).

In addition, playing digital games with educational elements can lead to an improvement of the quality of life for older people by helping them to strengthen ties with friends and thus decreasing loneliness. The digital online bingo game "Live Well, Live Healthy!" uses a bingo game to ask users questions about different aspects of well-being (nutrition, physical activities, psychological issues and social environment). The results of the user test showed that playing the game could increase the quality of life significantly (Sauvé et al, 2016).

Based on an analysis of different game designs, Soldati et al. (2020) described how social interaction between older people and players from another generation could be positively triggered and thereby increase subjective wellbeing. Just like the 'Ticket-To-Talk' principle, games could create an occasion for communication or "[…] motivate relatives to visit older people more often, so that the elderly are not forgotten" (Soldati et al., 2020, p.1).

The authors also refer to Ryan and Deci's self-determining theory in the context of playing games. Intergenerational players can be competent and autonomous in the game while feeling connected to other players through the game.

2.4 Tangible UIs for Older People

Tangible user interfaces (TUI) have a high potential to bridge the gap between the digital and the physical world. In particular for older people or people with dementia, it matters if digital technology could also be experienced physically. Especially physical everyday artefacts, which hold meaning for the older people's generation, help trigger a person's memories and mitigate barriers of acceptance (Spreicer, 2011). Bong et al. (2018) describe in a literature review that TUIs make digital technology more accessible because they "[…] can be a more natural, intuitive, and easier interaction for older people, which might also result in less cognitive and physical efforts required of them" (Bong et al., 2018).

In the following we outline three recent works in the area of tangible interfaces for gaming and for communicating over a distance.

An excellent example of gaming is the tangible serious chess game by Eichhorn and colleagues (2021). The tangible uses a tablet as user interface as well as a game board. Pieces are printed with conductive material to recognize the players' movements on the tablet. It is highly adapted to the needs of people with dementia. The authors provide different considerations for design aspects, like feedback, assistance or color themes. For example, the pieces are designed in a way that users can distinguish the figures from each other. Additionally, the game uses fewer pieces so that game complexity is low. Players can choose between three scenarios: the tutorial, training and play scenario, where as in the last scenario, one plays with a virtual opponent. This opponent adjusts to the cognitive skills of the user. The authors also implemented auditory feedback when players try to perform illegal or impossible moves. In all three levels, a companion supports the user through providing useful information and tasks. Last, the interface is highly customizable with different color themes and a 2D- or 3D-view and the design is very detailed for older people. Nevertheless, it lacks in initiating social interaction.

Another playful, but not game-based tangible user interface that fosters building up social closeness is the Story-Me system, a slot-machine-like device (Li et al., 2019). It focuses on playful "intergenerational story-sharing regarding life story and family memento story, between older adults living in nursing home and their children" (Li et al., 2019, p.245). The system consists of a tangible device for the older adults looking like a slot machine connected to a remote mobile application used by their children. Children can send photos and questions to the Story-Me system and the older adults use the slot-machine-like mechanic to switch between these trigger images or questions. If they want to reply and tell stories around them, they can record and send audio with two hardware buttons. The positive aspects of this work related to our research is the self-determined usage and the provision of means to establish playful rituals in intergenerational and social exchange.

Another system similar to the previous examples, is the "Grandtotem" (Butzer et al., 2020). It combines a remote mobile app used by family members, in this case, grandchildren studying abroad, with a tangible object for older people. Grandtotem functions in several ways as focal point for social rituals, including a photo frame and a relationship media album. (Butzer et al., 2020). The wooden rectangular device is equipped with touch screens at two sides, an analog photo frame on the third side and a hinge at the top to flip up a webcam. The tangible enables the older people to receive and send video messages in an easy way as well as browse through a gallery or enjoy a slide show. "The grandparent can also send a lightweight 'touch', by physically touching the base of the totem" (Butzer et al., 2020, p. 230) to the mobile app, which has been evaluated positively. It was found that users on both sides happily received video messages but were less keen on sending their own. Recommendations include that notifications need to be more visible and persistent. Last, the authors emphasized that other researchers should take into account that older users have to adapt to the technology first, that there might be physical barriers and that roles can change during interactions.

Summarizing, all prototypes reveal the necessity to understand how older people can adapt their individual ways to technology and design systems carefully with social rituals in mind. TUIs seem to work best if they keep focus on one or two primary functions.

3 HYBRID GAMING OVER A DISTANCE: CONCEPT DESIGN

We need to create a meaningful social practice as a reason for feeling connected to satisfy the psychological need for relatedness (Hassenzahl et al., 2012). Shove et al. (Shove et al., 2012) define social practice based on the three elements 'meaning', 'competencies' and 'material'. As designers and developers, we often design the material first. In the case at hand, the material needs to introduce a common topic to connect people over a distance. For example, a topic could be the weather, introduced through a weather station. Or a conversation about relatives, introduced through a digital photo book, showing the latest family event. We chose to use a board game as a trigger for engagement. Shared gameplay can be considered a meaningful activity across generations. While children naturally engage in play and start playing games more strategically around age 5, traditional board games are still a key social activity for older people (at home, in care homes, or in community centres). Even people with mild cognitive impairments or early-stage dementia often remember the rules of games played throughout their lives. In addition to the fun, playing known games also provides the players with the sense of competence and therefore self-determination. However, when playing remotely using a web interface this feeling of older adult's competence can be undermined by the difficulties of interacting with the technology.

To address this problem, we created the concept of hybrid gaming over a distance. 'Hybrid' refers to the combination of using a physical playfield that is technologically enhanced on the one side and a completely digital, web-based playfield on the other side. Both connect players with different competencies in using technology and different lifestyles. While the tangible UI provides a low threshold game experience for people who are not technology-savvy, the web interface allows people familiar with technology to use it wherever they want, even while on the go. Both UIs are connected via a network connection (e.g. a webserver). The artefacts are also paired with video communication technology, helping users communicate reasonably natural while engaging with the material in a meaningful and competence-based interaction. Thereby, it has the potential to create a new social practice in terms of Shove et al.'s (2012) theory.

In the following we provide a detailed technical description of our proof-of-concept prototype.

4 CASE: HYBRID LUDO

4.1 Design Concept

We implemented a hybrid version of the traditional board game Ludo, as it is a game that has been played by many generations and is still popular. Thus, it can be expected that most people know the rules, whether young or old. We created a physical interactive board game for older participants, including video conferencing functionality. A screen could be pulled out of the wooden game case. The case holds the interactive LED-based playfield. The physical figures and dice are in a drawer that can be opened on the side of the case. The tangible UI allows older people to play Ludo in the same way that one would do with the traditional board game. The only exception is that the player needs to confirm their move to transmit the information via the network to the digital game UI.

The (younger) relatives can use the web interface anywhere they want by simply accessing it through a computer, laptop, or smartphone. The web UI uses animations of the game figures to show their movements, while the tangible UI shows the online player's moves through LED lights. When a piece is "thrown out", the figure/light moves back into the starting circles. Rolling the dice on the web UI is done by clicking the corresponding button. The user of the tangible UI uses a real dice. In the following, we describe the implementation in detail.

4.2 UI Design Considerations for Older People

When designing for older people, some guidelines must be respected. The contrast vision and the hearing ability decrease. The decrease of color vision most of the time happens due to previous illness (Lord et al., 1991, Berninger et al., 1999). Hearing loss can be as high as 20db in the frequency spectrum most important for speech, between 500 Hz and 4 kHz (Hesse et al., 2014; Meyer-Eppler, 1950). To avoid frustration, interactions should be designed intuitively and directly (Burchardt & Uszkoreit, 2018). We tried to implement the guidelines by developing a tangible user interface with natural input and using bright, high contrast colors on the playfield as well as volume-adjustable sound output.

4.3 Implementation of the Tangible Ludo Game

4.3.1 General Hardware

We chose oiled oak wood for the outer case for the prototype unit, giving it a pleasant and valuable look and keeping it robust. To lower the weight, we milled off the inner parts of the case. We used MDF wood for the base plate. The inside (Figure 1) offers enough space for arranging electronic hardware like the pull-out display or the drawer. Facing the prototype from the front (Figure 2), two rotary knobs can be used to adjust the game's brightness and the system volume. In addition, three buttons are provided for further interaction, such as confirming a move.

4.3.2 Electronic Components

One of the critical components the player interacts with is the interactive playing field. It provides visual feedback of the opponent's position and the player's pieces using LEDs and recognizes their moves using hall sensors.

A classic ludo field can be represented by an 11x11 matrix, deriving a need of 121 LEDs and sensors. Accordingly, we designed a custom PCB

Figure 1.

1: Raspberry Pi 4B Mainboard
2: Pull-out display unit with microphone and webcam
3: ESP8266 SoC for discrete control of the matrix
4: 5W speaker
5: PAM8403 audio amplifier
6: 5V step-down converter
7: Drawer for playing pieces and dice

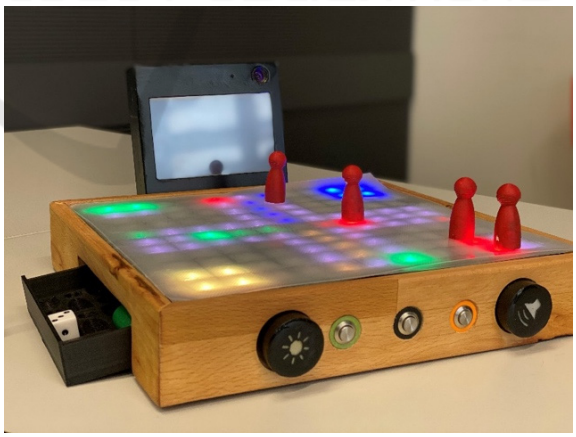

Figure 2: Front view showing controls.

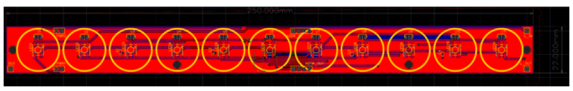

Figure 3: Single row PCB design.

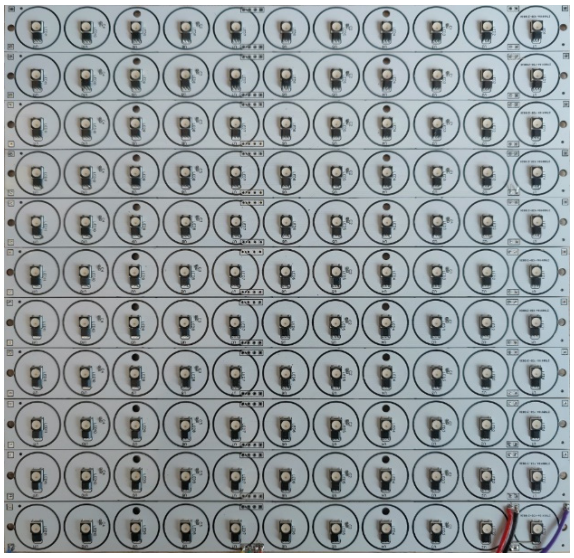

Figure 4: LED and sensor Matrix.

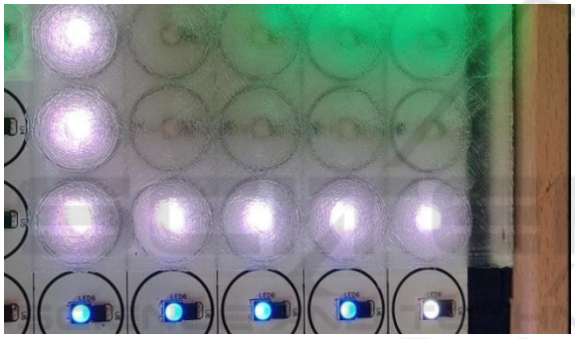

Figure 5: Diffusor array.

containing 11 WS2812b RGB LEDs, 11 AH3503 linear hall sensors, and a CD74HC4067 analog multiplexer (Figure 3). 11 PCBs are combined to a complete game matrix (Figure 4). In addition, the use of analog hall sensors, determining a higher sensitivity in magnetic field strengths and polarity, enables several playing pieces to be differentiated.

The PCBs are designed to connect the multiplexer's address inputs in parallel, and the LEDs are daisy-chained. Each row's multiplexer output is fed into a column multiplexer, generating one analog output for all hall sensors. At the same time, eight address pins are required for the multiplexers. As the AH3503 sensors can draw up to 11mA each, we included a ULN2803 Darlington array to switch off the sensors if not in use. Splitting the multiplexing into rows and columns by only using 11 of the 16 inputs enables direct addressing rather than

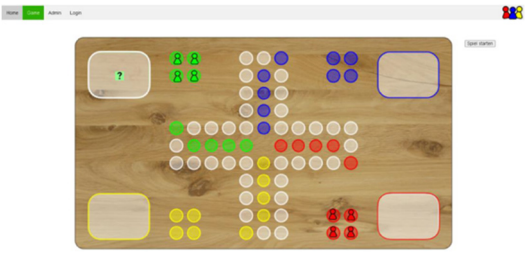

Figure 6: Game canvas of the web interface.

calculating the position of a sensor in the matrix. An ESP8266 SoC does the processing to simplify testing and programming. The connection is established via USB Serial, and simple commands can be used to control the matrix and retrieve the current positions of the play pieces. To diffuse the LEDs, we 3D printed a lens array that also serves as a playing field (Figure 5). Besides the matrix, we also integrated a 5-inch touchscreen that can be pulled out of the case's back and flipped up to present a video call with the opponent. The screen is attached with a standard full HD USB webcam and microphone. A 5W speaker powered by a PAM8403 amplifier inside the case provides an adequate audio output.

The prototype is based on a Raspberry PI 4B with 4GB of RAM running Raspbian, winning with a small footprint and sufficient CPU performance to host the web interface and manage video calls. The PI handles both communications with the electronic components, like the LED-matrix, and hosts a web application for logic and interfaces. We established the communication between the Raspberry and the matrix using the NodeJS based serial port library. A simple set of commands helps to minimize the serial port's traffic. For example, one character and three integers (*function, row, column, colour*) are sent to control one LED. A changed position of a piece can be requested from the sensor matrix, or the ESP8266 can auto-sent new coordinates as soon as a change occurs.

4.3.3 Web Interface

An Apache web server provides the web interface and the game logic written in JavaScript, based on the implementation by Felix Riesterer[1]. We modified the input routine to add interface compatibility with the prototype and chose a web interface to ensure a non-specific OS use on the opponent's device. The web interface contains an interactive ludo playing field in wood design, showing both the online player's and the opponent's positions (Figure 6).

[1] https://www.felix-riesterer.de/self/maedn/

5 DISCUSSION

We successfully implemented a proof-of-concept prototype for the described concept of 'hybrid gaming over a distance', thereby showing the technological feasibility of the introduced concept. The concept is based on our own experiences in designing solutions for technologically mediated socio-emotional communication of older adults and intergenerational and insights from the literature on creating closeness over a distance. The reason to choose a hybrid form of a tangible interface and a digital application is the multigenerational context. The combination lowers barriers for both target groups and potentially raises their acceptance. Each user might easily integrate this new social gaming practice over a distance in his or her individual's everyday routine.

The main limitation of the work presented is lack of involvement of the target audience throughout the project. At the beginning a participatory approach was envisioning with regular involvement of seniors recruited by a social senior care worker of the Caritas. However, due to the covid-19 pandemic, restrictions in meeting people placed a barrier to interact with the target group (i.e. people who are not used to digital devices or online video calling) and also to meet physically within the project team. Therefore, the development was done over a distance, and it was not possible to iteratively evaluate the concept in the wild with possible users. The social care worker was involved throughout the project giving valuable insights and feedback. We were finally able to test the prototype at the university with him representing the needs of the older adults and a younger employee who was not involved during the design and development.

While an in-situ evaluation is still essential to validate the concept and to improve the design, this first prototype test of the care worker already led to research questions, which will be answered in the ongoing course of the project. For instance, 'how important are the audio and video communication during the gameplay for both sides?' Especially since the prototype leaves some room for cheating on the game (e.g., when the older user does not move according to the pips on the dice), the video may support the other users to reveal the cheat. This can lead to emotional but also joyful interactions. We also hypothesize that just the gameplay does not have the power to create relatedness over a distance, but it could be reached in combination with at least audio and ideally video transmission. However, other hybrid activities over a distance, e.g., music-making, could satisfy the need for relatedness without conversation. More research needs to investigate the social practices around hybrid interactions and the resulting technical ecology. As soon as the pandemic situation allows, we will conduct user testing with the target group.

6 CONCLUSIONS

To sum up, we introduced the concept of hybrid gaming over a distance to mitigate the lack of meaningful, intergenerational communication in online video communication. We implemented a hybrid ludo game, which consists of a tangible board game for seniors connected to a digital application for younger people who would like to play and communicate with the older person. In addition, we proved the technical feasibility of the concept. Future work will focus on iterative testing and improvements towards a stable system.

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REFERENCES

Altschul, D. M., & Deary, I. J. (2020). Playing analog games is associated with reduced declines in cognitive function: A 68-year longitudinal cohort study. The Journals of Gerontology: Series B, 75(3), 474-482.

Armitage, R., & Nellums, L. B. (2020). COVID-19 and the consequences of isolating the elderly. *The Lancet Public Health*, *5*(5), e256. https://doi.org/10.1016/S2468-2667(20)30061-X

Berninger, T., Drobner, B., Hogg, C., Rudolph, G., Arden, G. B., and Kampik, A. "Farbensehen in Abhängigkeit vom Alter: eine Normwertstudie," (in ger), Klin Monatsbl Augenheilkd, vol. 215, no. 1, pp. 37–42, 1999, doi: 10.1055/s-2008-1034667.

Brooks S K, Webster R K, Smith L E, Woodland L, Wessely S, Greenberg N, & J, R. G. (2020). The psychological impact of quarantine and how to reduce it: rapid review of the evidence [revista en Internet] 2020 [acceso 28 de enero de 2021]; 395(10227): 912-920. *The Lancet*, *395*(10227), 912–920. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7158942/pdf/main.pdf

Bundesministerium für Familie, Senioren, Frauen und Jugend, Einsamkeitsemp-finden Älterer ist deutlich erhöht. [Online]. Available: https://www.bmfsfj.de/bmfsfj/aktuelles/alle-meldungen/einsamkeitsempfinden-aelterer-ist-deutlich-erhoeht-173816 (accessed: Aug. 22 2021).

Bong, W. K., Chen, W., & Bergland, A. (2018). Tangible User Interface for Social Interactions for the Elderly: A Review of Literature. *Advances in Human-Computer Interaction*, *2018*, 1–15. https://doi.org/10.1155/2018/7249378

Burchardt, A. and Uszkoreit, H. "Unterstützen, motivieren, interagieren –Gestaltung von Produkten und Services für Senioren," in IT für soziale Inklusion: Digitalisierung –Künstliche Intelligenz –Zukunft für alle, A, Eds., München, Wien: De Gruyter Oldenbourg, 2018, pp. 89–108.

Butzer, M., Levonian, Z., Luo, Y., Watson, K., Yuan, Y., Smith, C. E., & Yarosh, S. (2020, October). Grandtotem: Supporting International and Intergenerational Relationships. In *Conference Companion Publication of the 2020 on Computer Supported Cooperative Work and Social Computing* (pp. 227-231).

Cudjoe, T. K. M., & Kotwal, A. A. (2020). "Social Distancing" Amid a Crisis in Social Isolation and Loneliness. *Journal of the American Geriatrics Society*, *68*(6), E27–E29. https://doi.org/10.1111/jgs.16527

Eichhorn, C., Plecher, D. A., Golovnya, O., Volkert, D., Hiyama, A., & Klinker, G. (2021, July). Tangible Chess for Dementia Patients–Playing with Conductive 3D Printed Figures on a Touchscreen. In International Conference on Human-Computer Interaction (pp. 38-57). Springer, Cham.

Geyer et al., "Die Lebenssituation von Menschen mit Demenz und pflegenden Angehörigen während der Coronavirus-Pandemie Eine qualitative Studie," In Pflege, vol. 33, no. 4, pp. 189–197, 2020, doi: 10.1024/1012-5302/a000750.

Hassenzahl, M., Heidecker, S., Eckoldt, K., Diefenbach, S., & Hillmann, U. (2012). All You Need is Love. *ACM Transactions on Computer-Human Interaction*, *19*(4), 1–19. https://doi.org/10.1145/2395131.2395137

Hesse, G., Eichhorn, S., and Laubert, A. "Hörfähigkeit und Schwerhörigkeit alter Menschen," (in ger), HNO, vol. 62, no. 9, pp. 630–639, 2014, doi: 10.1007/s00106-014-2903-8.

Li, C., Hu, J., Hengeveld, B., & Hummels, C. (2019, June). Story-me: design of a system to support intergenerational storytelling and preservation for older adults. In *Companion Publication of the 2019 on Designing Interactive Systems Conference 2019 Companion* (pp. 245-250).

Lord, S. R., Clark, R. D. and WEBSTER, I. W. "Visual acuity and contrast sensitiv-ity in relation to falls in an elderly population," Age Ageing, vol. 20, no. 3, pp. 175–181, 1991, doi: 10.1093/ageing/20.3.175.

Meyer-Eppler, W. "Die Spektralanalyse der Sprache," (in 4), STUF -Language Typology and Uni-versals, 1-6, pp. 240–251, 1950. [Online]. Available: https://www.degruyter.com/document/doi/10.1524/stuf.1950.4.16.240/html

Pieri, M., & Diamantinir, D. (2010). Young people, elderly and ICT. *Procedia - Social and Behavioral Sciences*, *2*(2), 2422–2426. https://doi.org/10.1016/j.sbspro.2010.03.348

Powell J.A. and Arquitt. GE 1978. Getting the Generations Back Together: A Rationale for Development of Community Based Intergenerational Interaction Programs. The Family Coordinator 27, 4:
421. https://doi.org/10.2307/583446

Reis, L., Mercer, K., & Boger, J. (2021). Technologies for fostering intergenerational connectivity and relationships: Scoping review and emergent concepts. *Technology in Society*, *64*, 101494. https://doi.org/10.1016/j.techsoc.2020.101494

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Sacco, G., Lléonart, S., Simon, R., Noublanche, F., & Annweiler, C. (2020). Communication technology preferences of hospitalized and institutionalized frail older adults during COVID-19 confinement: Cross-sectional survey study. *JMIR MHealth and UHealth*, *8*(9), 1–7. https://doi.org/10.2196/21845

Sauvé, L., Renaud, L., Kaufman, D., & Duplàa, E. (2016). Can digital games help seniors improve their quality of life?. In International Conference on Computer Supported Education (pp. 179-192). Springer, Cham.

Shove, E., Pantzar, M., & Watson, M. (2012). *The Dynamics of Social Practice: Everyday Life and How it Changes*. SAGE Publications Ltd. https://doi.org/10.4135/9781446250655

Soldati, M., Zahn, C., Bildibay, D., Iseli, T., Leisner, D., Niederhauser, M., & Recher, M. (2020). Create Video Games to Promote Well-Being of Elderly People – A Practice-Driven Guideline. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *12208 LNCS*, 401–418. https://doi.org/10.1007/978-3-030-50249-2_29

Spreicer, W. (2011). Tangible interfaces as a chance for higher technology acceptance by the elderly. *Proceedings of the 12th International Conference on Computer Systems and Technologies - CompSysTech '11*, *July*, 311.https://doi.org/10.1145/2023607.2023660

Welsh, D., Morrissey, K., Foley, S., McNaney, R., Salis, C., McCarthy, J., & Vines, J. (2018). Ticket to talk: Supporting conversation between young people and people with dementia through digital media. *Conference on Human Factors in Computing Systems - Proceedings*, *2018-April*(April). https://doi.org/10.1145/3173574.3173949.