MagiBricks: Fostering Intergenerational Connectedness in Distributed Play with Smart Toy Bricks

Evropi Stefanidi
University of Bremen
Bremen, Germany
evropi@uni-bremen.de

Julia Dominiak
Łódź University of
Technology
Łódź, Poland
julia.dominiak@p.lodz.pl

Marit Bentvelzen
Utrecht University
Utrecht, Netherlands
m.bentvelzen@uu.nl

Paweł W. Woźniak
Chalmers University of
Technology
Gothenburg, Sweden
pawel.wozniak@chalmers.se

Johannes Schöning
University of St. Gallen
St. Gallen, Switzerland
johannes.schoening@unisg.ch

Yvonne Rogers
University College London
London, United Kingdom
y.rogers@ucl.ac.uk

Jasmin Niess
University of St. Gallen
St. Gallen, Switzerland
University of Oslo
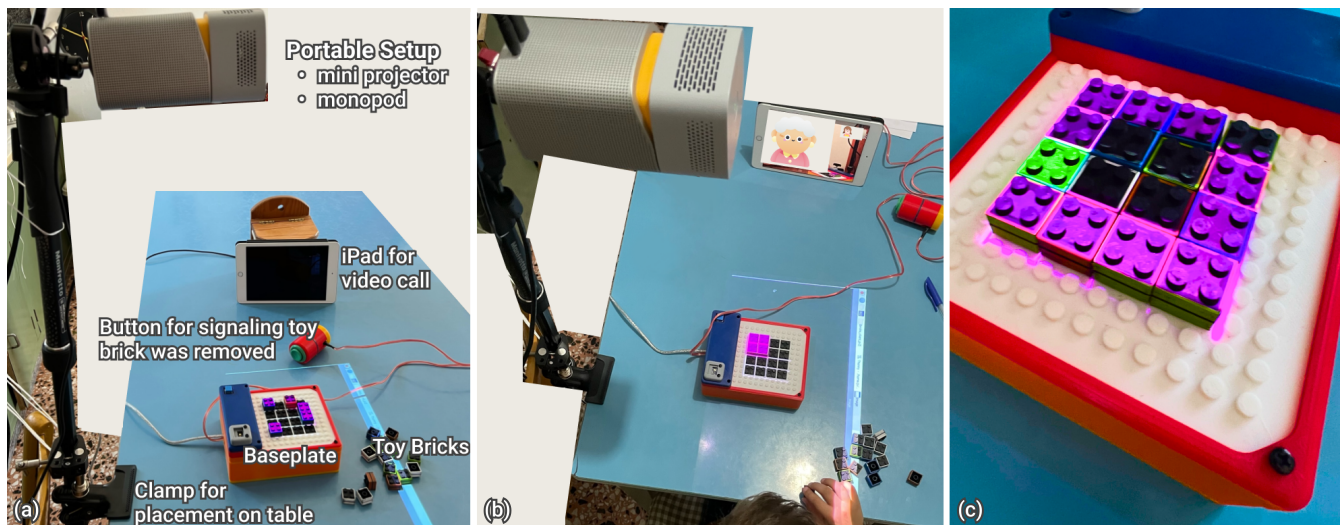Oslo, Norway
jasmin.niess@unisg.ch

Figure 1: (a) The study setup with the MagiBricks system, including the feedback system (portable projector, monopod and clamp), the smart toy bricks and baseplate, and a tablet for a video call between participants. (b) Child playing with MagiBricks with grandmother on a video call and colour feedback visible. (c) Detail of the smart baseplate whilst creating the "square task". Green-coloured feedback indicates where the other player just placed a smart toy brick. Pink-coloured feedback indicates where the other player has already placed smart toy bricks.

ABSTRACT

Playing together is crucial to the unique and invaluable bond between grandparents and grandchildren. However, co-located interactions and play can be limited due to time, distance, or pandemic-related restrictions. To facilitate distributed play, we developed MagiBricks, a system comprised of 3D-printed smart toy bricks and baseplates that provide feedback regarding their placement. The familiarity and appeal of toy bricks to both older adults and children make them ideal for intergenerational play. We conducted a within-subjects study with six grandparent-grandchildren pairs. We compared the interactions and perceived connectedness of the pairs while playing over a distance with either i) MagiBricks or ii) identical regular toy bricks. We found that MagiBricks affected communication dynamics, role taking, nature of play, and perception of connectedness during playtime compared to regular bricks, and were unanimously preferred. We contribute design implications for future systems leveraging (smart) tangibles and fostering intergenerational connectedness.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; **Interactive systems and tools**; **User studies**.

KEYWORDS

CCI; smart toys; tangible; distributed play; connectedness; toy bricks; blocks; 3D printing

1 INTRODUCTION

The bond between grandparents and grandchildren is unique; it differs from other family relationships and provides them with invaluable benefits [89]. For grandparents, these benefits include feeling joy, pride, and a sense of purpose and continuity by taking part in their grandchildren's lives [46, 48]. For grandchildren, grandparents can be invaluable life teachers, historians, nurturers, mentors and role models [49], while their shared activities can foster the child's self-esteem [48]. Research has demonstrated the importance of a close grandparent-grandchild relationship for mental health [40, 70] and how their playful interactions can particularly benefit their social communication and well-being [17, 48, 49, 58, 69]. However, various constraints can significantly limit their co-located interactions. Distance is such a constraint, made common due to trends such as globalisation, immigration, and the prevalence of nuclear families, leading to fewer co-located multi-generational families [2, 31, 72, 76, 96], and thus fewer opportunities for grandparents and grandchildren to engage in meaningful interactions [5, 31, 56]. Other constraints include time availability, lifestyle choices, and social circumstances such as divorce [43, 88]. Vetere et al. [85] characterise these constraints that lead to grandparent-grandchildren separation as physical, temporal, and social distance respectively. Moreover, the social distancing constraints imposed by the COVID-19 pandemic created additional obstacles in developing and maintaining close intergenerational relationships. Thus, social connectedness shifted to a remote, online experience, aided by technology. This shift was not entirely new; for instance, grandparents and grandchildren that live apart often rely on technologies for maintaining relationships, such as using phone calls and texting or video applications [89].

However, a known issue is that some of these systems are challenging to use by the grandparents, while they can also fail to engage and capture the interest of the children [89]. From a research perspective, the majority of work that aims to connect grandparents and grandchildren at a distance has focused on information exchange or storytelling/reading (e.g. [88, 89]). Few approaches have focused on the aspect of distributed play [18, 85], despite the fact that play between them is common and is crucial to building their relationship [85]. At the same time, smart toys are becoming increasingly common in children's homes [20], who readily interact with and adopt these technologies [53, 59], with pertinent research

receiving increasing interest within the CCI community [80]. Smart toys could thus open new avenues for promoting connectedness by enabling more interactive playing activities, coupled with the benefits of tangible interfaces. Since tangible interfaces merge physical objects with digital information, simplifying user interaction, they have the potential to improve older adults' acceptance of technology [77]. Furthermore, Fuchsberger et al. [26] found that grandparents and grandchildren who are physically distant often use tangible objects in their (online) interactions. Nevertheless, and despite the fact that toy bricks are both familiar and engaging for both older adults and younger children, to the best of our knowledge no previous work has explored their potential as smart toys to foster intergenerational connectedness during distributed play. In particular, toy bricks are an ideal tangible medium for intergenerational play, as playing with them does not require e.g. reading skills, which older grandparents or younger children may not have, lowering the acceptance threshold while being an engaging and fun toy. Hence, employing smart toys such as toy bricks to deliver enhanced play experiences between grandparents and grandchildren at a distance, fostering intergenerational connectedness is an under-explored opportunity.

To address this gap, we developed MagiBricks (Figure 1), a smart toy system consisting of smart toy bricks and a baseplate. The bricks are 3D-printed with conductive material allowing the detection of their position on the smart baseplate. Using a micro-controller, the MagiBricks system can provide real-time visual and audio feedback through a projector. Employing the construct of connectedness as a sense of being *actively involved* with another person [30], our research aims to actively involve grandparents and grandchildren with each other in distributed play, by promoting communication and collaboration. We aim to answer the following research questions:

- **RQ1**: How does a smart toy that allows for multi-modal feedback regarding players' actions affect the communication, collaboration, and perceived connectedness of grandparents and grandchildren while playing over a distance?
- **RQ2**: What kind of playful interactions are supported by a smart toy that allows for multi-modal feedback regarding players' actions?

To that end, we conducted a within-subjects study with six pairs of grandparents-grandchildren (N=12), where they took part in structured and unstructured distributed play while being on a video call, i) with our system -*MagiBricks condition (MB)*, and ii) with identical regular toy bricks -*Regular toy bricks condition (RB)*. Our analysis indicated that MagiBricks, and in particular the feedback they provided, positively affected the communication dynamics and perception of connectedness of participants during playtime compared to the regular toy bricks, and were unanimously preferred from the identical regular toy bricks. Furthermore, MagiBricks affected role taking behaviour and the nature of play. We contribute i) the MagiBricks system, ii) the study with six pairs of grandparents and grandchildren, as well as iii) design implications for future systems leveraging the affordances of smart tangibles and those aiming to foster intergenerational connectedness during play.

2 RELATED WORK

In this section, we contextualise our work within previous research on tangible interfaces and smart toys. We then present related work regarding intergenerational play and connectedness.

2.1 Tangible Interfaces & Smart Toys

Tangible systems are known to support collaborative play and social communication [54, 57, 86], thus presenting a suitable solution for engaging users in collaborative playful activities. Especially regarding children, HCI and CCI researchers have designed various tangible systems, in application areas such as games and learning. For example, Africano et al. [3] presented a multi-user interactive play system, employing a tabletop touch screen and tangibles, to promote collaborative learning about geography and culture while practising basic literacy skills. Li et al. [52] developed MemorINO, a tangible game that leads children to collaborate, naturally and interdependently. Regarding their implementation, some tangible interfaces use embedded micro-controllers. For example, Navigational Blocks [11] allow navigating and retrieving historical information through tactile manipulation and haptic feedback. Electromagnets embedded in the Blocks and wireless communication allow rearranging the Blocks to form different database queries.

Many tangible interfaces come in the form of bricks and building blocks, which can procure numerous benefits for children; for example, playing with blocks and puzzles helps them develop better spatial reasoning [28]. One of the most popular application areas of blocks is allowing children to program (e.g. [12, 35, 60, 78]). For instance, Tern [36] consists of jigsaw puzzle-like blocks, whose physical forms determine their ability to connect, thus employing physical constraints as a form of physical syntax for programming. Other block-based approaches focus on learning; for instance, Smart Blocks [29] for exploring the concepts of volume and surface area of 3D objects constructed by the user; or Flow Blocks [98], employing light feedback for exploring concepts relevant to understanding causality. With respect to previous tangible, block-based approaches, we present tangible 3D-printed smart toy bricks to enhance intergenerational distributed play, bridging the application areas of play, connectedness, and collaboration.

In recent years, smart toys have attracted particular interest in the CCI and HCI communities. This is evident in research regarding tangible musical toys [81] or health monitoring toys in the form of tangible cubes enhanced with sensors [87], as well as publications such as the special issue on "Smart Toys, Smart Tangibles, Robots and other Smart Things for Children" by Sylla et al. [80]. They identified the following emerging areas: new ways of play and education; playful learning and development of social skills; design tools and considerations; designing for therapy and training; children's understanding of data and data protection. Our work touches upon the aforementioned area of "new ways of play", extending it to "new ways of distributed intergenerational play". Below, we present examples of smart toys to illustrate and clarify the focus of our work. For instance, Storymat [71] is a play carpet that can record and replay children's stories, by detecting RFID-tagged toys that are placed upon it, and replaying an image of the moving toy by projecting it onto the carpet as well as playing the recorded audio. EnterTaible [83] consists of an LCD panel that can be placed on a table surface that allows for co-located collaborative play, by augmenting traditional board games. The system allows the detection of multiple concurrent inputs from fingers and objects. Moreover, Hinkse et al. [34] compared the Augmented Knights Castle, where the movement of figurines triggers audio output, to an identical, non-augmented toy. They showed that digitally augmented play environments promote different kinds of activity, such as replying to the figurines when they were talking. A follow-up study including children with autism [22] found that the augmented version of the toy promoted less solitary and more social play.

Aside from research, numerous commercial products and repositories of maker communities concerning smart toys and 3D-printed artefacts exist. Even if thoroughly investigating them is outside the scope of this paper, we briefly present two key examples to better contextualise our work. Regarding commercial toys, Neurosmith has marketed block-based tangible toys such as MusicBlocks, which allow children to create musical scores by inserting coloured blocks into the toy's body. With respect to 3D-printing and micro-controllers, approaches such as the Smart Chess Board [55] are noteworthy. It includes 3D-printed parts and micro-controllers, as well as LED lights embedded in the chess board for user feedback regarding the placement of the opponent's pieces. In contrast to our system, described in the next section, it does not automatically detect the placement of pieces; the user rather needs to provide this as input on a dedicated surface, by tapping on letters and numbers corresponding to the possible placements on the board.

We extend previous work by exploring tangible, 3D-printed smart toy bricks and baseplates that can detect brick placement, augmented with micro-controllers and a feedback system, in intergenerational distributed play settings.

2.2 Technologies for (Intergenerational) Connectedness & Play

Designing for connectedness has received ongoing research interest [27], with researchers employing design strategies such as awareness, joint action, and memories [32]. To that end, tangible interfaces have often been employed as communication support tools, addressing remote intimacy by exploring different sensory modalities, such as a pair of drinking glasses where one of them lights up when the remote partner drinks from their glass [16], or a picture frame which lights up when touched to enhance the communication between physically distant loved ones [14]. Especially regarding family members, various interactive artefacts and tangibles have been developed aiming to connect them [33, 43, 92]. The majority of technologies facilitating the connection between (remote) family members involve information exchanges and messaging systems [37]. For instance, Butzer et al.'s [9] Grandtotem is an asynchronous communication device that aims to support the relationship between grandparents and their adult grandchildren studying abroad by sharing images, viewing them as a gallery, and sending video messages. Binda et al. [6] also focused on facilitating intergenerational information sharing in family contexts, and in particular health information. They designed PhamilyHealth, a web-based photo sharing system for family members to share health-related photos with one another and to encourage a family-wide, sustainable, healthy lifestyle.

Many recent works have also focused on intergenerational story-telling. Wallbaum et al. [89] presented StoryBox, a tangible device that supports intergenerational connectedness by sharing photos, tangible artefacts, and audio recordings of everyday life between grandparents and their grandchildren. They deployed it with two families (children aged six to ten) and found that it could help bridge the technological gap between grandparents and grandchildren. Li et al. [51] presented Story-Me, a system facilitating intergenerational story-sharing between older adults living in a nursing home and their (adult) children, through a custom-made device that the older adults use to tell stories based on memory triggers from their children. Ambe et al.'s [4] Messaging Kettle included sensing and messaging capabilities and aimed to connect dispersed families through the routine of boiling the kettle. In a longitudinal study deploying the prototype, participants (older mothers and adult daughters) expressed feelings of everyday togetherness, nurturing their relationship at a distance. Vutborg et al.'s [88] storytelling technology probe allowed audio communication and sharing of virtual objects through a shared display set for each household. They deployed it with two sets of grandparents-grandchildren living apart (ages four to eight), and found that participants were keen to stay in contact through storytelling and personal photos. Family Story Play [66] allows grandparents and grandchildren to read physical storybooks together remotely, including an audio channel and page-sensing technology to determine if they are on the same physical page. Evaluation results were positive, as children were more engaged in long-distance communication than when using Skype, and the quality of the intergenerational interactions improved.

However, interactions between grandparents and grandchildren are often opportunistic, incidental, and playful [85], rather than focusing on information exchange. Limited research has employed the aspect of play to connect grandparents and grandchildren at a distance, despite play between them being common and crucial to building their relationship [85]. Davies et al. [18] already demonstrated that intergenerational relationships at a distance can be maintained via playful activities. They deployed Magic Boxes, in which items would be placed by each household and transferred by researchers between the grandparents and grandchildren of four families residing in different households, participating in a two-week study. This led some participants to use items they placed in the boxes as part of made-up games between them, such as guessing games and puzzles. Vetere et al. [85] explored intergenerational distributed play with the Collage system, enabling grandparents and grandchildren to send photos and text messages from a mobile phone to the system, manipulate these objects on their respective touch screens, and have this manipulation be synchronously replicated to the other. Evaluation of the system (children aged two to ten) showed that both grandchildren and grandparents enjoyed the new types of playful activities the system offered. Another example of research on intergenerational technologies that go beyond information exchange and focus on shared activities is the work of Chowdhury et al. [15]. They proposed designing for intergenerational distributed co-listening of music, as current technologies do not support collaborative music listening and conversation.

Nevertheless, and despite the benefits of manipulating tangibles, the opportunity of using smart toys by augmenting tangible toys,

such as toy-bricks, to facilitate intergenerational distributed play has yet to be explored. In particular, while previous work mostly focused on fostering intergenerational connectedness through systems facilitating messaging or storytelling/reading, we employ 3D-printed smart toy bricks that provide real-time visual and audio feedback about their placement, to enhance distributed play interactions and perceived feelings of connectedness of grandparents and grandchildren playing together at a distance, by fostering communication and collaboration between them.

3 MAGIBRICKS

Our research aims to actively involve grandparents and grandchildren with each other in distributed play, seeking to enhance their play interactions by making them feel connected to each other during their play. This active involvement includes communication and collaboration, and is based on the connectedness construct put forth by Hagerty et al. [30]. To that end, based on our design rationale and relevant related work, the following design decisions (DD) were taken. The first design decision was that the system would be **comprised of tangible artefacts (DD1)**. Tangibles can be understood as resources for communication [54, 57, 86] and shared activity [23–25]. Manual interaction with physical objects is observable and can enhance clarity due to their visibility [47], thus supporting social action, and awareness and coordination in a group [74]. Moreover, they are often employed in collaborative settings, e.g. many tangible systems aim to foster collaborative learning (e.g. [79, 82]). Therefore, tangible artefacts are suitable for shared intergenerational activities, and their features are in line with our goal of promoting communication and collaboration while interacting with the system, in order to enhance users' feelings of connectedness while playing. Second, since toy bricks afford familiarity and appeal to both younger children and older adults, we designed MagiBricks to augment regular toy bricks. Given our aim to foster communication and collaboration between grandparents and grandchildren in distributed play, we decided to make **custom 3D-printed smart bricks with detectable positions to provide both visual and audio feedback (DD2)**. Yuill et al. [94] already showed that augmenting toys with audio to capture children's attention increased cooperative play. By utilising both visual feedback, in the form of colour, and audio feedback, in the form of short melodies when toy bricks are added or removed, we aimed to promote collaboration and communication between grandparents and grandchildren. In the context of our study, we used tablets for video calling to allow participants to communicate with each other. Furthermore, Yuill et al. [95] identified three mechanisms through which multi-user interfaces can support collaboration: mutual awareness, mutual control, and mutual availability. Based on this, we **employ the concept of mutual awareness (DD3)**, i.e. being aware of the other users' actions, in order to support collaboration. In more detail, MagiBricks provide both colour and sound feedback **in real-time** regarding the placement of the bricks of the other user, thus allowing mutual awareness of the system's state at any moment. Designing for awareness is also in line with Hassenzahl et al.'s [32] strategies to mediate feelings of connectedness.
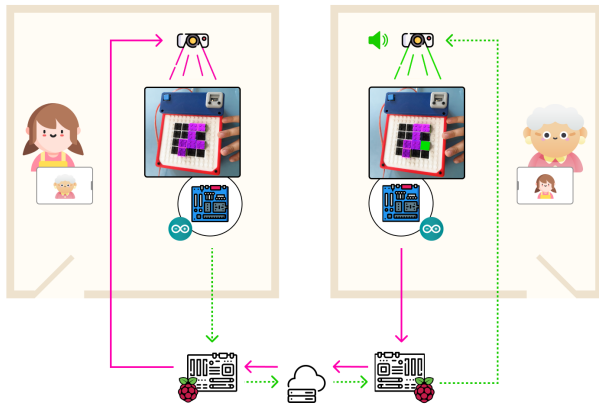
Figure 2: Visualisation of the system's architecture. The grandchild and the grandparent are in different rooms (at a distance), each having the same setup in front of them. We illustrate the data flow from the Arduino inside the smart baseplate to the corresponding python client (running on Raspberry Pi). The data continues to the server and from there to the other client, and then to the projector that displays a dynamically constructed image on top of the baseplate and a corresponding sound. In the pictured example, the grandchild placed a toy brick and so the corresponding position on the grandmother's baseplate becomes green, followed by a short sound. (This Figure has been designed using images made by Freepik from Flaticon.com)

Based on those design decisions, the MagiBricks system was implemented. We drew inspiration from papers describing interactive paintings for entertainment on pop-up books [61, 65] or paper [19, 39, 75] for the use of conductive composite materials (paint and filaments for 3D printing). We also looked at interactive surfaces consisting of conductive PLA, such as 3D pictures and user interfaces [8, 73], mock-ups supporting urban planning [62], or extending interaction with touch screens [44]. The following subsections present the system in detail (see Figure 3 for the basic components).

3.1 Smart Toy Bricks & Baseplate

The prototype was designed using Autodesk Fusion 360 and was 3D-printed using standard PLA filament and conductive material [38]. The prototype is packed in a case with the brick-detecting baseplate on top and a a chamber with the Arduino Uno Rev3 controller underneath, equipped with a shield that facilitates the connection of all cables. The main sensors responsible for detecting the elements are the Adafruit MPR121 touch module. The pins of the sensor can detect contact with the skin or an element with high resistance, as it uses capacitive measurement. A single module has 12 such pins. Two wires are led out of the casing: the extension for the "brick removal" button that signifies the removal of a brick, as the current system version is not able to distinguish between removing and adding, and a second cable that powers the Arduino and sends
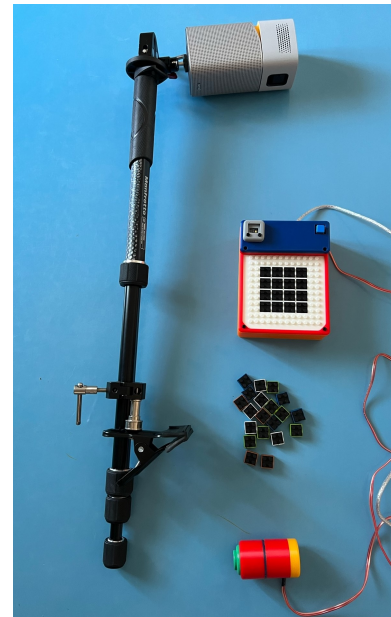

Figure 3: Basic system components: monopod with clamp and attached projector for the feedback system, smart baseplate (including button for brick removal), and smart toy bricks.

information to a Raspberry Pi via UART communication. This is used for data exchange as a web socket client (feedback system). The 3D-printed toy bricks look similar to other commercially available ones, e.g. LEGOs®. A single piece of 2x2 dots (comprising a brick) consists of two types of material: a black core, printed from conductive PLA, and a coloured shell, printed from classic coloured PLA, so that each toy brick has a colourful casing around its black (conductive) core. Additionally, as the hand does not come into contact with the conductive material when removing bricks while playing with them (most users only grab the brick's outer shell when removing it), we added lines of conductive paint around them (Bare Conductive Electric Paint), thus allowing touch detection on the sides of each toy brick as well. The smart baseplate, consists of a 4x4 matrix and is filled with 2x2 dot plates. Similar to the smart toy bricks, it consists of two types of materials: conductive PLA, as a detection plate, and PLA as a base, which allows the separation of individual 2x2 plates and their even distribution. Due to their size and complexity, elements from different materials were printed separately and then glued together. In order to connect the printed elements with the electronics, a dedicated printed circuit board (PCB) was designed for easy connection of individual detection points with the pins of the touch sensor. The conductive elements were connected with the PCB using the heat set insert technique (fusing metal elements, e.g. wires or threads inside the plastic). Each tile is connected to individual pins of the touch sensor located on the PCB, which transmits information directly to the Arduino main module through I2C communication (Figure 4). A PCB mechanically supports and electrically connects the electronic components using conductive tracks, pads, and other features etched from one or more sheet layers of copper, laminated onto and/or between

sheet layers of a non-conductive substrate. The prototype recognises elements on one of sixteen designated points on top of the baseplate. Nevertheless, toy bricks can also be added on top of each other, in order to build vertically, since the addition of a toy brick will still be detected by the capacitance of the finger in contact with the top-most element of a vertical structure, transmitted through the conductive core of the toy brick all the way to the baseplate.

3.2 Feedback System

Regarding the feedback system (Figure 2), Player 1 can experience feedback from player 2 (and vice versa), in the form of sound and colour: green when a brick is added, red when a brick is removed, and pink for showing all the current positions where player 2 has placed a brick. The colour feedback is made possible by a custom set-up we created, using a portable projector, a monopod, and a clamp to attach the monopod to a surface (e.g. a table). Thus, the projector casts the appropriate image on top of the baseplate, based on the client program running on each Raspberry Pi. An example of the colour feedback can be seen in Figure 1c. We implemented an external feedback system rather than an internal light source e.g. including LED lights directly inside the prototype, for two reasons; one, having individual LED light sources inside each brick was impossible due to their small, LEGO®-like size, and two, due to the physical properties of the detection points inside the baseplate, which are crucial for brick detection. In particular, the conductive PLA material fully blocks light and cannot function as an optic fiber element, prohibiting illumination of vertical brick structures from below. Therefore, we chose to superimpose the colour feedback, which allows players to receive colour feedback even with multiple bricks stacked vertically, as this is projected on the top-most toy brick.

The architecture of the feedback system employs a web-socket-based server-client model with two clients, and the programming logic followed is event-based. The server, invisible to the players, is Python-based and communicates with two Raspberry Pis, which are in the same room as each player, running the client code. Once a change is detected (capacity change on top of the baseplate), the Arduino transfers the information about the position of a brick and whether it was added or removed from this position to the Raspberry Pi connected to it. Thus, client 1 communicates the information about the position of interest and whether a brick was added or removed by player 1 to the server, which in turns passes that information on to client 2. Once client 2 receives the information about a change, it logs the information on a structure that keeps track of all the positions where bricks have currently been placed. Then it dynamically updates the image cast by the portable projector on top of the baseplate, so that the position of interest becomes green if a brick was added there, or red if it was removed. This is accompanied by sound feedback, with a different 2-second audio clip being played based on whether a brick was added or removed. Finally, after 3 seconds, the projected image is updated again, so that nothing is projected in the position of interest if the previous colour was red, or a pink colour is projected if the previous colour was green. Thus, player 2 always has an overview of any changes that player 1 makes on their baseplate,
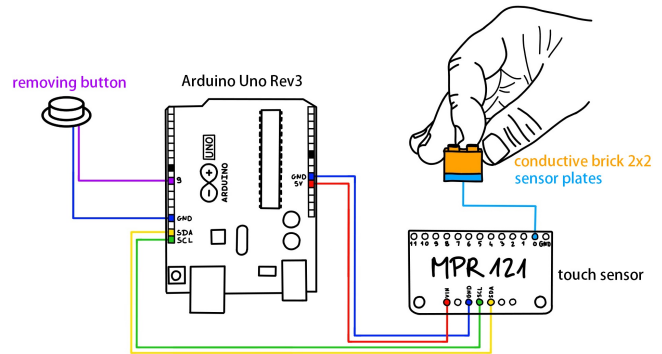

Figure 4: Smart toy brick detection circuit.

Table 1: Participant Demographics.

Pair	Ages & Genders	Toy Bricks Experience	First Condition
GP1 | GC1	61 (F) | 10 (F)	yes | yes	RB
GP2 | GC2	74 (F) | 10 (F)	no | yes	RB
GP3 | GC3	71 (F) | 5 (M)	little | yes	RB
GP4 | GC4	52 (F) | 4 (F)	yes | yes	MB
GP5 | GC5	58 (F) | 4 (F)	yes | yes	MB
GP6 | GC6	77 (M) | 7 (M)	no | yes	MB

while also keeping track of all the positions where player 1 placed toy bricks.

4 USER STUDY

We conducted a within-subjects study in the European Union with six pairs of grandparents-grandchildren (N=12), to investigate how MagiBricks affects their communication, collaboration, and perceived connectedness while playing over a distance (RQ1) and how they interact with each other while playing with MagiBricks (RQ2). Participants were engaged in two different conditions, which we counter-balanced: i) *MagiBricks condition (MB)*, where they interacted with the MagiBricks system, and ii) *Regular toy bricks condition (RB)*, interacting with regular toy bricks. To remove the influence of different toy brick quality, we used the same physical toy bricks but disabled the feedback of the MagiBricks system. Ethics approval was obtained by the Ethics Committee of Utrecht University (ERB Review Bèta S-21606) prior to the study.

4.1 Participants

We recruited N = 12 participants, six grandparents aged 52-77 ($M = 65.5, SD = 9$), five female, and their respective six grandchildren, aged 4-10 ($M = 6.6, SD = 2.5$), three female. Hereinafter, we refer to the six grandparents as GP1-GP6, and to their grandchildren as GC1-GC6. Participant demographics and the first condition they experienced are shown in Table 1. All participants had no colour vision deficiency, and all grandparents lived in their own household. We focused on this age group since grandchildren can already play with toy bricks, construct structures and have basic

communication skills at age 4, while on the other side of the spectrum, research shows that children aged 10 and below are more likely to play and communicate with their grandparents, as this can decline when they enter the preteen phase [21]. Participants were recruited through word-of-mouth and the personal network of the authors, using a snowball sampling strategy. The participants took part on a voluntary basis. Each pair of grandparent-grandchild received a board game that they could play together, as a token of appreciation for their participation.

4.2 Procedure

We conducted a within-subjects exploratory study, where participants engaged with the two conditions, *MB* and *RB*, in one of two different sessions, each taking place on separate days. Participant pairs were randomly but evenly assigned to one of the two conditions for the first session, in order to counterbalance. The study sessions took place at a convenient location for the participants, a house provided by a contact person of the authors. Two people from the research team were present throughout the entire study duration. Each participant was in different rooms of the house, together with a researcher, at a distance from each other and with closed doors, ensuring that they could only hear each other through the video call, thus creating a distributed play situation that was "over a distance". Each session lasted between 20 and 65 mins (M = 39 mins, SD = 13.6). Participants were able to take a break if they wished and were offered snacks and water.

At the beginning of the first session, participants were greeted and taken to the room where the grandparent's play setup was located. After the entire process was explained to them, participants were able to ask questions and it was pointed out once again that participation was voluntary, and they could stop their participation at any point during the study. Informed consent forms were signed, by both the grandparent and a parent/legal guardian of the children, in case they had not already been signed, and verbal assent from the children was obtained. Only one mother wished to stay and quietly observe the session, while the rest did not stay for the duration of the study. Following this introductory phase, demographic data were collected and the child was guided to a separate room with the leading researcher, where the second play setup was located. A brief semi-structured interview with each participant took place, in order to establish the current playing and communication habits of the grandparent-grandchild pair and prior use of toy bricks and relevant technologies for remote communication and play. The researcher also engaged in a short casual conversation with the child to help them feel comfortable, and reduce any anxiety, shyness, or uncertainty. Apart from the interview, the same process was followed in the second session, in order to re-establish rapport with the participants, remind them of the process, and give them the opportunity to ask any questions before beginning.

The system setup present in each of the two rooms is visible in Figure 1a. In the *MB* condition, the researcher additionally explained to participants the meaning of each colour they could see as feedback (green, red, and pink). The researcher also explained the function of the button to signal brick removal in the *MB* condition. Each participant was assured that the researcher would be the one pressing the button when needed, so that participants do not have an additional task and can focus on their shared playtime. In each session (*MB* or *RB*), participants were asked to engage in three different playing tasks, including both structured (create specific structures) and unstructured play (interact with the toy bricks freely), as well as a "tic-tac-toe" game. Participants were instructed that they could play together as they wished, and could communicate via video call the entire time. All participant pairs received the same instructions. For the structured play part, participants were asked to create the following structures: i) a square, ii) a tower, and iii) an animal. In particular, the researcher instructed the participants that the task's goal was that they both build each structure. However, they were informed that they could create each structure the way they wanted it (e.g. the tower could be as high as they wanted). Also, they were free to communicate with each other to the degree they wished to. Following this first playing task, the grandparent and grandchild played the well-known game of tic-tac-toe, with which all participants were familiar. To clarify, in tic-tac-toe players take turns placing their symbol on an empty square to get three in a row horizontally, vertically, or diagonally. The game ends in a tie if all squares are filled without either player getting three in a row. In our study, participants used their bricks as their symbols, placing them on the 3x3 part of the grid that resided on the bottom-left corner of the baseplate closest to them. Finally, participants could engage in free play, where they could create any structures they wanted. Again, the participants were instructed that they could communicate to the degree they wished. However, this time the goal of the task was that each one creates a structure that was not predefined. The participants could either create the same structure or a different one each. If they wanted, they could also ask the researcher for ideas of what to build, in case they needed inspiration.

At the end of each session, each participant took part in a short debriefing semi-structured interview, to elicit their opinions about the toy bricks they had just played with (e.g. fun, ease-of-use) and their perceived feelings of connectedness. The interview protocol is available in the Supplementary Material. Additionally, at the end of the second session children were asked to complete the Again-Again Table [67], asking them which activities they would do again. For younger children that could not read, the researcher read the questions as well as the available answers out loud.

4.3 Data Collection & Analysis:

During the study, we collected both qualitative data by video recording the sessions and interviews, as well as quantitative data, using the Again-Again Table [68] questionnaire, indicating whether children would like to do a certain activity again [68]. The qualitative data was analysed in an iterative, collaborative manner. The interviews were transcribed verbatim, the video recordings were transcribed non-verbatim, with immediate translation from the original language to English. Based on the interaction analysis method [41, 42], the expressions, comments, actions and exhibited behaviour during the sessions, along with time stamps were logged in Excel sheets together with the transcribed dialogues. The data of the video observations and interviews were open coded, using the MaxQDA software. After an initial round of open-coding the data from three grandparent-grandchild pairs by two authors, an initial

coding tree was discussed and agreed on. Then, one researcher coded the remaining material. Finally, we used affinity diagramming and derived four themes, which are presented in the next section. This process is in line with Blandford et al. [7].

5 FINDINGS

Here, we present out findings based on the analysis of our user study. The quantitative data, comprised of the grandchildren's answers to the Again-Again Table questionnaire are available in the Supplementary Material. Based on our qualitative inquiry, four themes were conceptualised from the data: *Communication Dynamics*, *Nature of Play*, *Role Taking*, and *Perceptions of Connectedness*. Before discussing these themes in more detail, we outline general impressions from our study. In general, both conditions were perceived positively, with participants enjoying playing with both MagiBricks and the regular toy bricks. They often looked at each other and smiled upon completion of a structure (GP6 and GC6, RB), or when one successfully followed the other by looking at the feedback (GP6 and GC6, MB). All participants enjoyed the feedback, but particularly the children immediately had a smile on their faces when they *"saw the baseplate light up"* (GC2, MB), often pointing at the place where they understood their grandparent placed their toy brick: *"Oh, again! It's magic!"* (GC3, MB) or at the "pink-coloured" places where they could see their grandparent already had toy bricks: *"Grandma put it here, here, here, and there!"* (GC4, MB) This is further corroborated by the grandchildren's answers to the Again-Again Table, which demonstrates that all children enjoyed playing with MagiBricks, and already hints at their preference of playing with MagiBricks over the regular bricks, which we describe in more detail below. This is also clearly reflected in the answer of GC1, one of the oldest children, who would not want to play again with the regular toy bricks with her grandmother, but rather with MagiBricks. Below, our findings for the two conditions, *MB* and *RB*, are comparatively described and illustrated with excerpts from the sessions.

5.1 Communication Dynamics

The first theme focuses on how the communication dynamics between the grandparent-grandchild pairs differed between the two conditions. The differences spanned two dimensions: i) the communication frequency and "intensity", i.e. how much they communicated and interacted with each other, and ii) the communication content, i.e. what they communicated about and when. Regarding the first, there was a clear difference between the two conditions, as participants communicated and interacted more with each other in the *MB* condition, with frequent interactions about how to make a structure, what to build, as well as discussing the feedback. The intensity and frequency of interaction significantly decreased in the *RB* condition, where there were multiple instances with a prolonged lack of interaction between the participants. For instance, GC6 continuously ignored his grandparent in the *RB* condition when he was asking what they should make in the unstructured play part of the session, and instead talked to the researcher. In contrast, GC6 continuously engaged with his grandfather in the *MB* condition, making sure that his grandparent understood that what he wanted to build was a house, *"Okay grandpa?" (GC6, MB)*, and carefully

watching where his grandfather placed his toy bricks, pointing it out when they were not placed the same as his own *"Grandpa, not there!" (GC6, MB)*.

Our analysis also showed a difference in the topics (communication content) that participant pairs talked about and when this occurred. In more detail, participants more frequently engaged in richer-in-content conversations in the *MB* condition, communicating about how to make the various structures with the toy bricks, including asking for help and giving instructions, and about the feedback from the system: *"Tell me how you do it, so I can watch you, and make it as well!" "Okay, I take the green one and I put it there, see?" "I do the same [name of child], here you go!" (GP1 and GC1, MB)*. This was additional to conversations about beginning or completing a structure, which were the main topics of conversation for participants in the *RB* condition.

5.2 Nature of Play

A key difference between the two conditions was the nature of play that the grandparents and grandchildren engaged in. While in the *RB* condition participants mostly built their own structures without collaborating, both during the structured and the unstructured play, playing with MagiBricks seemed to have the exact opposite effect. In particular, even though the activity itself remained the same in both conditions, our analysis showed that MagiBricks, by allowing participants to always be aware of where the other player placed their toy bricks, changed the play conceptualisation, from an individualistic to a collaborative activity. Participants seemed to adapt to a different kind of play in the *MB* condition, where structures had to be built together, with one participant placing their bricks first and the other following. This led to children assuming "new rules", and specifically thinking that it was "wrong" when they and their grandparents were not building the exact same structure. For instance, GC2 noticed that her grandmother was not placing her toy bricks in the same place during the structured play, and tried to help her when *"she did it wrong" (GC2, MB)*. Both grandparent and grandchildren participants wanted to ensure they were building the same thing in the *MB* condition, and that the other could follow. This materialised in various ways, for example leading them to press again on top of the toy bricks they had already placed to make sure their feedback was coming through (GP2-GC2, MB), and converse with each other about whether they could see their current movements, *"Did you see what I just removed grandma?" (GC1, MB)*, or notice from the pink-coloured feedback that some toy bricks were missing and giving out instructions to fix that: *"Grandpa, you have not put a brick on the orange one!" "So I should put one here now" "Yes, put one where I did!" (GC6 and GP6, MB)* .

On the contrary, in the *RB* condition the majority of participants built their structures separately in both the structured and unstructured playing tasks, with significantly less interaction and conversation between them. Verbal instructions sometimes became too complicated (*RB*), resulting in confusion on either the grandparents' (in the case of GP4) or the grandchild's side (in the case of GC5), or in the grandparent having to repeat the same instructions several times without success (GP5 and GC5, RB). GP5 noted the lack of feedback in their second session (*RB*) as negative, and expressed this to the researcher: *"Now there is no colour feedback? Now*

I won't be able to help him. I won't be able to see I mean" (GP5, RB).
Notably, GC3, GC5, and GC6 were lifting and tilting the baseplate
to show what they had created to their grandparents through the
camera, demonstrating the importance of visual feedback.

In comparison to the other two playing tasks (structured and
unstructured play), the importance for the feedback offered in the
MB condition, was more prominent in the tic-tac-toe game. In order
to successfully play the game (in both the *MB* and *RB* conditions),
participants were required to collaborate and coordinate the place-
ment of bricks. Therefore, in the *RB* condition, participants needed
to verbally explain to each other where they had just placed their
bricks for the game to continue, as this information was not relayed
in another way, i.e. by the feedback. This led to some issues, as
participants had difficulties with communicating this with only
verbal input, leading to either restarting the game, or turning to
the researcher for help.

5.3 Role Taking

The third theme we identified was role-taking. As presented in the
previous theme, a key difference between the two conditions was
the participants collaborating and wanting to build the same struc-
tures in the *MB* condition. This contributed to the emergence of two
player roles: the leader, and the follower. These roles were assumed
by both grandparents and grandchildren. In the *RB* condition, the
role-taking theme was identified only for the grandparents of the
two youngest children, GP4 and GP5. On the other hand, in the *MB*
condition the theme was identified in all participant pairs. For most
participant pairs, the role-taking was very prominent throughout
their *MB* sessions, and the roles were even exchanged from one
to the other throughout a specific session. Below we describe in-
teractions that occurred i) when children were the leader, and ii)
when grandparents were the leader. When grandchildren were in
the lead, they were guiding their grandparents, by placing their toy
bricks one by one so the grandparents could see the feedback and
copy their moves. This was also frequently accompanied by verbal
instructions, or the children verbally articulating their actions, such
as GC1 narrating her moves while making an "ant": *"And then we
do the same on top!" "From the other side?" "Yes!" (GC1 and GP1, MB).*
Additionally, grandchildren in the lead were helping their grandpar-
ents when they asked for it, and this was particularly facilitated by
the system's feedback, which they used to achieve this. Grandchil-
dren also assumed the role of the "technology expert", explaining
how the MagiBricks system worked to their grandparents, for in-
stance reminding them that toy bricks could only be placed on the
black 4x4 baseplate and not the white surroundings, *"We can't place
the bricks on the white part!" (GC5, MB).* Interestingly, grandchildren
assumed the role of the leader only in the *MB* condition. Regarding
grandparents in the lead, while there were instances where they
were verbally guiding grandchildren by giving them instructions
in both conditions, in the *MB* condition grandparents would use
the system's feedback as their main instruction tool. In particular,
grandparents placed their toy bricks first, so their grandchild would
see the feedback and be able to copy their move. It is worth noting
that we observed an obvious benefit in having the feedback for fol-
lowing instructions, as there were various cases where difficulties

arose from trying to follow verbal instructions without it, which of-
ten led to the grandchild turning to the researcher who was present
in the room for help. In both conditions, grandparents played the
role of the encouraging supporter, by prompting them to start with
creating a structure or continue with placing the next toy brick,
reassuring them -*"Take your time!" (GP3, RB)* -, and praising them
-*"Good job! Now continue in the same line" (GP5, MB).*

5.4 Perceptions of Connectedness

The fourth theme engages with the different perceptions of connect-
edness while playing, both between the grandparent and grandchild
participants, as well as between the two conditions. Our analysis
showed that the aspects that made participants feel connected to
each other varied between the two conditions. On the one hand,
children did not identify any specific aspect that made them feel
connected with their grandparents when asked about this in in-
terview after the *RB* condition, while the two older children, GC1
and GC2 could identify such aspects in the *MB* condition. Grand-
parents could identify aspects that made them feel connected in
both conditions, however, the aspects differed across the two condi-
tions. To elaborate, aspects that made grandparents feel connected
to their grandchildren in the *RB* condition were the fact that they
were playing together (GP3), that they were having a video call
while playing which allowed them to talk (GP2), or the competition
and process of playing the tic-tac-toe game (GP1, GP4). However,
in the *MB* condition, their perception of connectedness changed
to *"making the same thing"* (GP1, GP4, GP5, GP6), *"following each
other's instructions"* (GP1, GP4), *"seeing what the other was doing
through the feedback"* (GP6, GC2), and *"communication and collabo-
ration"* (GP2, GP3, GP5, GC1). This illustrates the determining role
that feedback and its effects on communication, collaboration, and
conceptualisation of the play had on the perceived connectedness
of participants.

6 DISCUSSION

Our study showed that a tangible smart toy that enables a continu-
ous state of mutual awareness through visual and audio feedback
can positively affect the perceived connectedness of grandparents
and grandchildren while playing over a distance *(RQ1)*. Participants
found it much easier to create structures together with MagiBricks
and found playing with MagiBricks more enjoyable and preferable
to regular toy bricks *(RQ2)*. Additionally, our findings showed that
MagiBricks shifted the nature of play between the participant pairs
(RQ2). Specifically, participants seemed to automatically adapt to a
new conceptualisation of the same game, where "unwritten rules"
dictated they should build their structures together. This led to
enhanced communication between them, to collaboration, and to
the emergence of interchangeable leader-follower roles within the
game *(RQ1, RQ2)*. Below, we reflect on our findings and explore how
and why MagiBricks, and in particular the feedback they provided,
had this effect on the play interactions and connectedness of the
grandparent-grandchildren pairs. We also reflect on implications
for future research.

Our findings regarding the effects of MagiBricks on communica-
tion dynamics, nature of play, and perceptions of connectedness,
indicate that designing for intergenerational connectedness can

be facilitated by employing feedback as a mechanism for fostering mutual awareness, leading to enhanced communication and collaboration. We speculate that the real-time multi-modal feedback of MagiBricks fostered feelings of co-presence, i.e. sensing that one can perceive others and that others can actively perceive them [63], thus enhancing communication and fostering collaboration between the pairs. Casanueva et al. [13] already demonstrated the close link between collaboration and co-presence. Additionally, our findings revealed differences in the participants' perceived connectedness between the two conditions. Those differences particularly highlighted how participants felt connected to each other while playing because of the feedback and their resultant collaboration. Our findings are in line with Hinske et al. [34] and Farr et al. [22], who found that an audio-augmented castle toy increased social play and collaboration compared to an identical non-augmented version. We extend these findings by demonstrating the positive effects of multi-modal feedback on social play and collaboration, showing how this is valid not only for co-located settings but also in distributed play contexts. Smart toys can thus present new opportunities for fostering communication and collaboration in distributed play settings. Therefore, **our work demonstrates how smart toys employing real-time multi-modal feedback can lead to mutual awareness and foster users' perceived connectedness during distributed intergenerational play.**

Furthermore, the feedback of MagiBricks served as a trigger for conversation, affecting the nature of play and conceptualisation of the activity and driving grandparents and grandchildren to assume certain rules and roles within that context. Within this changed concept, participants wanted to build the same structures and used the feedback not only as a guide to do so, but as a way to enforce this new rule that their structures should be the same. This contrasted to the more individualistic game concept that was followed by the majority of participants in the *RB* condition. Kraut et al. [50] already showed that pairs who collaborate remotely to complete collaborative visual problem solving, e.g. puzzles, can benefit from a shared visual space, as it can facilitate communication by allowing monitoring each other's comprehension. Our analysis points to how a smart toy employing visual feedback to create this shared visual space can enhance communication and lead to collaboration in the case of grandparents and grandchildren playing in distributed settings. Overall, the augmentation that MagiBricks offered seems to have captured participants' attention, serving as a guide for their interactions while playing. This guide nudged participants to stay inside the constraints provided by the visual feedback, e.g. leading them to assume that placing bricks outside those constraints was "wrong" or "against the rules". Therefore, our findings show that the feedback led participants to change the way they interacted both with the toy, as well as with each other. This is in line with Hinske et al.'s [34] findings that digitally augmented play environments can encourage different forms of play than non-augmented ones. We extend research on tangible interfaces, which are known to naturally use constraints to communicate rules without having to explicitly state them [74], by showing how **smart toys, augmented with multi-modal real-time feedback, can lead to the generation of rules that would otherwise need to be explicitly communicated. Particularly, feedback could lead to changing the nature of (playful) activities, and in particular**

their conceptualisation from individualistic to collaborative ones.

Regarding the changed interaction between participants with respect to role taking, interestingly, grandchildren assumed the role of the leader only in the *MB* condition. It should be noted that GC4-GC6, who had completed the *MB* condition first and assumed leader roles, did not continue with this role taking in their second, *RB* session. It therefore seems that MagiBricks placed children in a position of power, which playing with the regular toy bricks did not achieve. It empowered them to assume the expert role and give instructions, feeling confident and enabled to do so. The underlying reason could be twofold. We hypothesise that, one, it could be attributed to children usually being apt with technology, even at a younger age, and grandparents either expecting their superior digital skills, or wanting to empower and nurture them by allowing them to be the "expert". Grandparents often assume mentor roles [49], but within this digital form of distributed play they could assume the role of the less knowledgeable party, allowing grandchildren to become the teacher [1, 17, 97]. This manifested in grandparents encouraging grandchildren to take the leading role by asking them questions about how to complete specific steps. The second reason, co-existing with the first, could be that the specific features of MagiBricks led to the children feeling empowered to take the lead. Vetere et al. [85] already explored roles grandparents and grandchildren assume during different types of co-located activities, and found that grandchildren could assume the role of an unconfident follower, seeking reassurance from their grandparent giving instructions. In our case, we speculate that the continuous mutual awareness of each other's actions via the real-time feedback provided children with a sense of security and certainty in the distributed play setting, as they were ensured that not only could they have a direct overview of their grandparents' actions, but also that their grandparents could see theirs. This potentially provided children with reassurance, to not only assume the role of apprentice or imitator [85], but to also become leaders themselves. Relating this back to our original goal of designing for connectedness, Kearney [45] described "empowered connectedness" as "a sense of having a safe place within a community and a meaningful role to play". Therefore, it could be argued that systems employing MagiBricks's features could lead to empowered connectedness, by providing the certainty of real-time feedback and allowing children to take on the meaningful role of the leader/instructor. This also relates to the concept of mutual control presented by Yuill et al. [95], which constitutes a behaviour mechanism that can underlie systems fostering collaboration. Therefore, providing them with both mutual awareness and control could have contributed to children feeling empowered to take the lead. Designing for empowerment has been receiving increasing interested in the CCI community [84]. For instance, pertinent research has addressed the topic of intergenerational distributed co-design with the goal to empower children who are geographically distributed to have an active role in the design of artefacts that are ultimately meant to be used by them [90]. **We extend previous work on technologies that seek to empower children, by demonstrating how collaborative systems that allow for mutual awareness and control, e.g. via feedback, can empower even younger children to take leading roles in a collaborative setting.**

6.1 Ways Forward & Limitations

Based on our findings, we highlight possible ways forward for systems that utilise feedback and tangibility. **Firstly, future systems could leverage feedback and tangibility in the context of collaborative systems or scenarios where it is desirable that children learn collaboration or turn-taking.** An example application could be exploring the use of systems like MagiBricks for supporting children with ADHD [64], who typically struggle with social interactions, impulsivity, and turn-taking [91]. However, before applying the system in such a context, further studies should be conducted with a larger sample size to further consolidate our findings. In addition, the experience of interacting with MagiBricks is a hybrid one between a digital game and regular toy bricks. We speculate that feedback and tangibility could enable players to feel that they could manipulate something on the other end of the divide. The term "divide" here means both the physical distance between grandparents and grandchildren, as well as the well-known generational gap that deems grandchildren more technologically fluent and grandparents often reluctant to adopt and use new technologies. These aspects of feedback and tangibility could enhance an illusion of control compared to e.g. a computer game, due to the interaction with concrete physical material. Wallbaum et al. [89] already suggested that bridging the digital with the non-digital could facilitate scaffolding between the different generations.

Additionally, it is worth noting that two pairs (GP1-GC1 and GP4-GC4) experienced some feedback latency in the *MB* condition due to an unstable internet connection, which was subsequently resolved. No effect was observed, neither in their interaction before and after the latency issue, nor in comparison to other participant pairs. Specifically, participants expressed out-loud that they could not see each other's actions anymore, without this short interruption leading to decreased engagement or significant time off task. When this latency occurred, the researchers briefly explained that this was a limitation of the system and that it should work again shortly.

It also becomes particularly interesting to explore smart tangibles in the context of Mixed Reality (MR), replacing the video call that we used in our study and allowing for full-body virtual representations of the players. This would add a different layer to the digital part of the experience, by allowing grandparents and grandchildren to co-exist in the same space, albeit virtual, and interact with systems like MagiBricks, rendering the experience a mixture of visual, audio, and tangible feedback that seeks to enhance their feelings of connectedness. **Future work that seeks to bridge spatial and generational divides should take advantage of the affordances of tangibles and of different modalities of feedback, and explore how the resulting "illusion of control" affects connectedness in different settings, e.g. in MR environments.** Deploying MagiBricks in MR settings could also address certain limitations of the current prototype, such as knowing how many bricks are placed vertically by virtually superimposing toy bricks in the MR environment. Furthermore, future research could explore the use of systems like MagiBricks over a longer period of time, investigating their utility as situated artefacts, as well as how often they are used, and how long they are usefully employed. This, however, is no simple task, as evaluating systems long-term and especially whether participants stay engaged after repeated use is

not often addressed in CCI research as it can be challenging [93]. Finally, future studies could deploy similar systems during both co-located and distributed play, to investigate how the feedback and tangibility aspects affect each type of play, and how each could help grandparents and grandchildren build upon their previous interactions.

We recognise that our work is subject to certain limitations. Our sample size of six grandparent-grandchild pairs was rather small for conducting meaningful quantitative analysis. However, our sample size, being the most common sample size within HCI research [10], and a primarily qualitative approach are in line with similar work (e.g. [43, 85, 88]). Even though the age of our child participants is similar to related studies (e.g. [88, 89]), future work should explore potential age-related effects. For example, role-taking was present *only* for GP4 and GP5 in the *RB* condition, which could be related to GC4 and GC5 being the two youngest children in the study, as this might have affected GP4 and GP5 knowing they have to help out more, in comparison to older children. Nevertheless, the sessions we conducted were rich in information and allowed us to derive implications for future systems employing tangibility and feedback towards fostering connectedness.

7 CONCLUSION

In this paper, we presented MagiBricks, a system consisting of 3D-printed smart toy bricks that provide visual and audio feedback about their placement on a smart baseplate, for enhancing intergenerational distributed play. We conducted a within-subjects study with six pairs of grandparents and grandchildren. We compared the interactions and perceived connectedness of the participants when playing over a distance in two conditions: i) with MagiBricks (*MB*) and ii) with identical regular toy bricks (*RB*). Playing with MagiBricks enhanced the communication and collaboration between participants, leading to increased feelings of connectedness while playing over a distance. Our findings suggest that tangible artefacts that combine tangibility and feedback, leading to mutual awareness and control, can actively affect the conceptualisation of a (collaborative) activity, can lead to empowerment, and can provide suitable experiences that foster intergenerational play and connectedness over a distance. We hope that this paper will inspire further inquiry into how smart tangibles can foster connectedness between family and friends.

8 SELECTION AND PARTICIPATION OF CHILDREN

The study and its protocol were approved by the Ethics Committee of Utrecht University (ERB Review Bèta S-21606). The study was explained to the children's legal guardians, who gave their informed consent for inclusion before participation, as well as to the children, who were asked for a verbal agreement to participate. They were informed that they could stop and opt out of the study at any point and for any reason, and their data would be excluded, without any negative consequences. A total of six children took part in the study (five female, and one male). The children, along with their grandparents, were invited through word-of-mouth and personal contacts of the authors, using a snowball sampling strategy. All

participants' personal data were stored securely, and all personally identifiable data were removed.

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