Smart Tangibles: Fostering Connectedness Across Geographic Boundaries

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Supporting interpersonal connectedness and playful activities between users of different ages offers many well-being benefits. Novel interactive artifacts such as smart toys can help to foster connectedness and encourage play even when being geographically apart. Playing, both with peers and older individuals constitutes the most important activity for children's development. It supports social and emotional development and provides scaffolding opportunities. Yet, due to the current pandemic situation, the opportunities to facilitate play and social interactions have been limited. In this position paper, we envision how smart tangibles could contribute to fostering connectedness and play. We explore how to augment popular children's toys such as bricks and modeling clay and present a preliminary discussion of opportunities and challenges related to our approach. Finally, we outline next steps for future research that supports engaging, playful interactions beyond geographic boundaries.

CCS Concepts: • **Human-centered computing → Interactive systems and tools**; **Collaborative and social computing systems and tools**.

Additional Key Words and Phrases: smart toys, distance learning, play, connectedness, bricks, modeling clay

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1 INTRODUCTION & BACKGROUND

Developmental psychology research demonstrated the benefits of manipulating tangible objects [20] and the importance of play for learning, cultivating children's imagination and building social skills and relationships [2, 11, 17, 28]. While

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the importance of children's interaction with each other during playful activities is apparent, the COVID-19 pandemic and the resulting social isolation have forced a change in children's social lives, affecting their interaction with other people in real-life settings. We envision that smart tangibles can help mitigate such challenges and open new avenues for promoting social connectedness, thereby enabling more interactive remote playing and learning experiences. However, it remains a challenge how to effectively design interactions for such tangibles for remote play, so that they optimally benefit children and families.

Fuchsberger et al. [6] noted the ongoing interest in the HCI community to design for discourse and connectedness. Several tangibles and interactive artifacts have been designed to connect family members [10, 37], couples [14, 19, 25] and friends [36]. For instance, Ryokai et al. [22] explored technologies for capturing naturally occurring laughter and different ways of representing laughter in tangible forms. Their study showed that participants enjoyed preserving and interacting with laughter, and that the tangibility created the opportunity for a shared re-experience of precious moments. Another example comes from a study by Heshmat et al. [10], who designed three artifacts called Spark, Kinetic and Timeknot, aiming to support family members connecting across different time zones. The artifacts enabled users to share their daily experiences in an asynchronous manner with a loved one. Participants reported that interacting with the artifacts felt like receiving gifts, and that they supported connection, despite the physical distance. StoryBox [33] is a tangible storytelling system focused on fostering intergenerational connectedness, enabling grandparents and grandchildren to share daily stories over a distance. It allows sharing photos, tangible artifacts, and audio recordings of everyday life in an asynchronous manner, thereby bridging the intergenerational technological gap.

These examples illustrate that tangibles offer an opportunity for enhancing discourse and connection between users of different age groups. Inspired by the aforementioned examples, we envision how specific materials can foster play and connectedness, even when the playmates are not physically together. To that end, Smart Tangibles could be used as a mix of physical materials and virtual feedback and data.

2 EXPLORING TANGIBLES

Tangibles have been used in various domains and for different purposes. They can be made of different materials and include a range of material properties (e.g. size, shape, texture, temperature, weight) that can be associated with digital representations to convey information [16]. Children associate different materials with meanings through "material essences", feel, and tactile preference (e.g. wood is often associated with musical instruments, and felt with clothing) [23]. Materials discussed in previous work on tangibles for children include, inter alia: wood [23, 40], plastic [23], felt [23], silicone [23], and sand [7]. For instance, George et al. [7] performed a study with children aged 4-5 using the AR Sandbox, a conventional sandbox with depth colored representations projected onto the sand's surface, to investigate how it's used to enhance their spatial skills. They found that children's active and dynamic manipulation of the space of the AR Sandbox, along with a range of socio-cultural contexts and tools, assisted in enhancing their spatial abilities. In this position paper we focus on malleable materials such as modeling clay [12, 35], and bricks [34, 38].

2.1 Bricks

Playing with bricks brings many advantages such as learning to recognize shapes and colors and developing manual skills [21]. Furthermore, while playing together, children develop cooperation and communication skills [29]. Along with the development of technologies contained in the brick elements, systems for learning to program mobile structures made out of bricks have emerged, such as vehicles or robots [13, 27]. Nonetheless, most people still want to use bricks as building blocks to construct and arrange fantasy structures of their liking. In response to this demand, a market has emerged that offers applications for virtually designing custom buildings and shapes (e.g. [26]), offering a selection of customizable elements (e.g. changing colors, shape). These systems facilitate the design of fantasy structures and development of instructions, making it possible to transfer the virtual world to actual real bricks [15, 18, 32].

However, there is still no technology to convert the model or even the position of individual bricks on the build plate to a digital form. We are currently developing an intelligent build plate that detects the position of elements in 2D and 3D planes, using customized 3D-printed elements. The system uses specialized materials and a set of sensors connected to micro-controllers. Users can build creations of large dimensions and the base has a modular structure. This allows effectively and playfully recording and recreating the process of assembling a particular structure. The resulting system can facilitate cooperation when constructing structures for people who are not physically together. Analyzing the position of bricks on the build plate will allow to remotely and smoothly transfer and mirror information about the progress made, and error-checking will be possible by proofing the steps taken during the brick-building. Specifically for children, the system would facilitate scaffolding, as parents/grandparents can help children in the building process.

2.2 Modeling Clay

Modeling clay, often known under the commercial brand Play-Doh, and other malleable materials are very familiar and appealing to children [35]. modeling clay can help children improve their fine motor and spatial skills and logical-mathematical intelligence [4, 9, 30], as well develop their imagination, creativity, expression and literacy skills [9, 31]. Moreover, playing with modeling clay can be rewarding for children, as they feel competent [31], thereby increasing their self-efficacy.Modeling clay also fosters social and emotional development, from developing self-concept and self-control, to relationships and interaction with peers, e.g. cooperation, sharing, taking turns, negotiating [9, 31]. Previous work has mainly focused on (i) mixed-reality games using materials such as modeling clay and cardboard [1], or clay [35] to create characters or objects, which are then reflected in the virtual world, (ii) circuitry learning with electronics and modeling clay [12], and (iii) "remixing toys" by imprinting them into a clay-covered surface, to digitize, edit them, and produce new 3D-printed objects [5]. We are currently developing a platform which will allow children to create figures and objects with modeling clay to use in stories they create and share with their friends in the virtual world, using AR. Storytelling has many known benefits for children, such as fostering communication, collaboration, creativity, and retention skills [39] and is an effective tool to introduce matters on values and emotions to children [8]. We aim for this to be a collaborative storytelling experience that allows children to feel connected to their playmates via shared story characters and narratives.

3 FOSTERING CONNECTEDNESS

We explore how bricks and malleable materials can be transformed into Smart Tangibles. We expect those to enable children who play together to experience a sense of connectedness even when they are not physically together, aided by the tangible nature of the materials and the aforementioned benefits they procure. In addition to connectedness among peers, we believe that intergenerational connectedness can be fostered. In particular, the two materials we discuss are a good fit to support this: modeling clay and bricks have been available on the market for more than 70 years, making them well known by the majority of adults. Also, the psychological benefits for adults to interact with clay are well established [24] and an increasing number of adults has started using LEGO bricks to foster mindfulness [3].

Preliminary scenarios, which we have ideated include (i) multi-sensory collaborative storytelling over a distance, where children create characters, objects, and stories, and share them with peers who receive virtual representations, (ii) real-time feedback during structure constructions with bricks, where children can see and make changes in a synchronous manner, and (iii) children learning programming together using interactive bricks over a distance. In particular regarding the second scenario, it could promote intergenerational play and collaboration, as a more skilled parent or grandparent demonstrates how to create a complex structure, thus supporting scaffolding and socialization between different user groups at the same time.

We conducted informal interviews with parents of young schoolchildren, regarding the impact that the confinement due to the COVID-19 pandemic has had on their engagement and motivation, and found consistent results pointing to difficulties caused by social isolation; all parents reported that their children had troubles staying engaged during remote learning, due to losing the direct contact with their friends and teachers. We thus believe that supporting tangible, playful interactions for children across geographic boundaries is more timely than ever. Challenges involved in this endeavor include (i) planning of co-design sessions to elicit correct and sound user-requirements (ii) ethics concerns and data privacy issues, especially given the involvement of children and (iii) assessing the effectiveness of the system(s) after implementation, as social connectedness is not a quantitative measure.

4 CONCLUSION

In this position paper, we shared our vision of how interactive bricks and modeling clay can facilitate social interaction by enabling playing and learning together while being physically apart. We introduced the first steps of developing our interactive bricks and preliminary insights from initial, informal interviews. We discussed how materials such as modeling clay and bricks could foster social connectedness between remote users of different age groups and illustrated our vision with starting points such as providing real-time feedback during remote structure construction using bricks. Finally, we identified challenges for future IDC research in this area.

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REFERENCES

[1] José María Blanco, Pascal Landry, Emanuela Mazzone, and Narcís Parés. 2010. PIPLEX: tangible experience in an augmented reality video game. In *Proceedings of the 9th International Conference on Interaction Design and Children*. 274–277.

[2] Peter Blatchford, Anthony D Pellegrini, and Ed Baines. 2015. *The child at school: Interactions with peers and teachers*. Routledge.

[3] Simon Bourdeau, Annemarie Lesage, Béatrice Couturier Caron, and Pierre-Majorique Léger. 2020. When Design Novices and LEGO® Meet: Stimulating Creative Thinking for Interface Design. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–14.

[4] Natalie Else, Kerry Thompson, and Don Thompson. 1998. Playdough Pays Off. *Australian Primary Mathematics Classroom* 3, 3 (1998), 4–7.

[5] Sean Follmer and Hiroshi Ishii. 2012. KidCAD: digitally remixing toys through tangible tools. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 2401–2410.

[6] Verena Fuchsberger, Janne Mascha Beuthel, Dorothé Smit, Philippe Bentegeac, Manfred Tscheligi, Marije Nouwen, Bieke Zaman, and Tanja Döring. 2020. Designing for Tangible (Un-) Connectedness. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference*. 409–412.

[7] Rhys George, Christine Howitt, and Grace Oakley. 2020. Young children's use of an augmented reality sandbox to enhance spatial thinking. *Children's Geographies* 18, 2 (2020), 209–221.

[8] Laurence R Goldman. 2020. *Child's play: Myth, mimesis and make-believe*. Routledge.

[9] Judith Harries. 2015. Playing with playdough. *Early Years Educator* 17, 2 (2015), xiv–xvi.

[10] Yasamin Heshmat, Carman Neustaedter, Kyle McCaffrey, William Odom, Ron Wakkary, and Zikun Yang. 2020. FamilyStories: Asynchronous Audio Storytelling for Family Members Across Time Zones. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–14.

[11] Carollee Howes, Kenneth H Rubin, Hildy S Ross, and Doran C French. 1988. Peer interaction of young children. *Monographs of the society for research in child development* (1988), i–92.

[12] Samuel Johnson and AnnMarie P Thomas. 2010. Squishy circuits: a tangible medium for electronics education. In *CHI'10 extended abstracts on human factors in computing systems*. 4099–4104.

[13] Jim Kelly. 2006. *LEGO Mindstorms NXT: The Mayan Adventure (Technology in Action)*. Apress.

[14] Robert Kowalski, Sebastian Loehmann, and Doris Hausen. 2013. Cubble: A multi-device hybrid approach supporting communication in long-distance relationships. In *Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction*. 201–204.

[15] Sheng-Jie Luo, Yonghao Yue, Chun-Kai Huang, Yu-Huan Chung, Sei Imai, Tomoyuki Nishita, and Bing-Yu Chen. 2015. Legolization: Optimizing LEGO Designs. (2015).

[16] Anna Macaranas, Alissa N Antle, and Bernhard E Riecke. 2012. Bridging the gap: Attribute and spatial metaphors for tangible interface design. In *Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction*. 161–168.

[17] Sonia Mastrangelo. 2009. Play and the child with autism spectrum disorder: From possibilities to practice. *Int. journal of play therapy* 18, 1 (2009), 13.

[18] Daniel Mendes, Pedro Lopes, and Alfredo Ferreira. 2011. Hands-on Interactive Tabletop LEGO Application. In *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology*.

[19] Florian'Floyd' Mueller, Frank Vetere, Martin R Gibbs, Jesper Kjeldskov, Sonja Pedell, and Steve Howard. 2005. Hug over a distance. In *CHI'05 extended abstracts on Human factors in computing systems*. 1673–1676.

[20] Jean Piaget. 2013. *Play, dreams and imitation in childhood*. Vol. 25. Routledge.

[21] Mitchel Resnick. 2007. All I really need to know (about creative thinking) I learned (by studying how children learn) in kindergarten. In *Proceedings of the 6th ACM SIGCHI Conference on Creativity & Cognition*. 1–6.

[22] Kimiko Ryokai, Elena Duran Lopez, Noura Howell, Jon Gillick, and David Bamman. 2018. Capturing, representing, and interacting with laughter. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. 1–12.

[23] Jinsil Hwaryoung Seo, Janelle Arita, Sharon Chu, Francis Quek, and Stephen Aldriedge. 2015. Material significance of tangibles for young children. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction*. 53–56.

[24] Michal Sholt and Tami Gavron. 2006. Therapeutic qualities of clay-work in art therapy and psychotherapy: A review. *Art Therapy* 23, 2 (2006), 66–72.

[25] Samarth Singhal, Carman Neustaedter, Alissa N Antle, and Brendan Matkin. 2017. Flex-N-feel: emotive gloves for physical touch over distance. In *Companion of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing*. 37–40.

[26] 3D Slash. 2021. *3D Slash*. Retrieved April 19, 2021 from https://www.3dslash.net/index.php

[27] Daniel E. Stevenson and James D. Schwarzmeier. 2007. Building an Autonomous Vehicle by Integrating Lego Mindstorms and a Web Cam. (2007).

[28] Helen Street, David Hoppe, David Kingsbury, and Tony Ma. 2004. The Game Factory: Using Cooperative Games to Promote Pro-social Behaviour Among Children. *Australian journal of educational & developmental Psychology* 4 (2004), 97–109.

[29] Qiming Sun and Pinata Winoto1. 2019. An Intelligent LEGO Tutoring System for Children with Autism Spectrum Disorder. In *Proceedings of the 2019 the International Conference on Pattern Recognition and Artificial Intelligence*. 56–59.

[30] Panggung Sutapa, Yudik Prasetyo, Fatkhurahman Arjuna, and Hadwi Prihatanta. 2018. Differences of Influence of Playing Playdough and Puzzles on Fine Motor Skills and Logical-Mathematical Intelligence in Early Childhood. In *2nd Yogyakarta International Seminar on Health, Physical Education, and Sport Science (YISHPESS 2018) and 1st Conference on Interdisciplinary Approach in Sports (CoIS 2018)*. Atlantis Press.

[31] Mallary I Swartz. 2005. Playdough: What's Standard about It? *Young Children* 60, 2 (2005), 100–109.

[32] Tiffany Tseng and Mitchel Resnick. 2012. Building Examples: Media and Learning Affordances. In *Proceedings of the 11th International Conference on Interaction Design and Children*. 176–179.

[33] Torben Wallbaum, Andrii Matviienko, Swamy Ananthanarayan, Thomas Olsson, Wilko Heuten, and Susanne CJ Boll. 2018. Supporting communication between grandparents and grandchildren through tangible storytelling systems. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. 1–12.

[34] Danli Wang, Yang Zhang, Tianyuan Gu, Liang He, and Hongan Wang. 2012. E-Block: a tangible programming tool for children. In *Adjunct proceedings of the 25th annual ACM symposium on User interface software and technology*. 71–72.

[35] Xuan Wang and Adrian David Cheok. 2011. ClayStation: a mixed reality gaming platform supporting playful learning for children. In *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology*. 1–2.

[36] Huaxin Wei, Dianya Hua, Eli Blevis, and Zitao Zhang. 2019. MemoryReel: A Purpose-designed Device for Recording Digitally Connected Special Moments for Later Recall and Reminiscence. In *Proceedings of the Thirteenth Int. Conf. on Tangible, Embedded, and Embodied Interaction*. 135–144.

[37] Jun Wei, Xuan Wang, Roshan Lalintha Peiris, Yongsoon Choi, Xavier Roman Martinez, Remi Tache, Jeffrey Tzu Kwan Valino Koh, Veronica Halupka, and Adrian David Cheok. 2011. CoDine: an interactive multi-sensory system for remote dining. In *Proceedings of the 13th international conference on Ubiquitous computing*. 21–30.

[38] Peta Wyeth and Gordon F Wyeth. 2001. Electronic blocks: Tangible programming elements for preschoolers. (2001).

[39] Yan Xu, Hyungsung Park, and Youngkyun Baek. 2011. A new approach toward digital storytelling: An activity focused on writing self-efficacy in a virtual learning environment. *Educational Technology & Society* 14, 4 (2011), 181–191.

[40] Oren Zuckerman, Saeed Arida, and Mitchel Resnick. 2005. Extending tangible interfaces for education: digital montessori-inspired manipulatives. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. 859–868.