



REVIEW ARTICLE



<https://doi.org/10.1057/s41599-024-04043-9>

OPEN

Methodological considerations of technology co-design with families and design implications on mediating family connectedness from empirical research

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Co-designing technologies with families for mediating family connectedness is an important area of research. However, the literature directly investigating both co-design with families and family connectedness is limited. This review aims to address this gap by analysing empirical studies on co-designing technologies with families for family connectedness. Seven relevant articles published from 2005 to 2019 were identified from the Scopus database and by snowballing from reference lists. The included articles were analysed on the methods and tools adopted, challenges in co-designing with families, scenarios of mediated family connectedness, and concerns related to technology. The findings show that various methods and tools have been used to engage families with six types of family ties. The key challenges of co-designing with families include scheduling conflicts, recruiting diverse families, technical issues, and setting free participants' creativities in co-design activities. The main scenario that requires technology-mediated family connectedness is remote shared/separated activities between family members. Although there are limitations regarding the limited number of samples, this review provides an overview of the empirical research about technology co-designing with families for mediating connectedness. The design and research implications drawn from the findings can contribute to future design practices of communication technologies and interdisciplinary research related to communication, social science, and technology.

Introduction

The importance of the physical and mental well-being of people of all ages of establishing social connectedness has long been highlighted in psychological and social science research (Lee and Robbins, 1998; Rettie, 2003; Townsend and McWhirter, 2005; van Bel et al., 2009). From the turn of the century, with wider coverage of Internet services and the emergence of new Information and Communication Technologies (ICTs), people have seen the

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potential benefits of using technologies to mediate social connectedness regardless of location and time (PrakashYadav and Rai, 2017; Ryan et al., 2017; Caliandro et al., 2021; Chen and Lunt, 2021). The study of Hassenzahl et al. (2012, pp. 1–2) declares the importance to people’s psychological well-being of using technologies to support the human needs of ‘relatedness’, ‘connectedness’, or ‘togetherness’: that is, ‘the general feeling of being related to significant others’ such as family members and intimate partners. Addressing people’s social connectedness with families has thus been a focus of participatory design research (abbr. PDR) for technology development (Yarosh et al., 2011, p. 138; Isola and Fails, 2012, pp. 44–46; Christensen et al., 2019, pp. 375–376).

Reviews have investigated empirical studies about technology for mediating social connectedness (Ibarra et al., 2020; Bhowmick and Stolterman Bergqvist, 2023). The study of Ibarra et al. (2020) summarises technological interventions for realising long-distance communication to achieve social well-being among older adults, providing overviews on strategies of technological interventions, the psychological dimensions of social well-being to target through interventions, and measurements to evaluate those dimensions. They also list the technology and devices used for social well-being interventions and find two factors—learnability and perceived difficulty of use—that can influence older adults’ adoptions of technology for remote communication (Ibarra et al., 2020, pp. 8, 11). Similarly, the review of Bhowmick and Stolterman Bergqvist (2023) investigates studies of older adults’ attitudes towards using technology to mediate social connectedness with close families, relatives, or friends. They reveal the trend of creating tangible, ubiquitous technologies for the social connection of older adults since the early 2000s and summarise the requirements of tangible user interfaces for this group into seven themes to inform future design (Bhowmick and Stolterman Bergqvist, 2023, pp. 4–5).

However, the two review articles by Ibarra et al. (2020) and Bhowmick and Stolterman Bergqvist (2023) are not directly about family connectedness or co-designing with families. Although design professionals may have an intended group of people in mind who would be mainly served by the technology, given that the technology is to be designed for mediating social connectedness, all stakeholders that would have experiences with the technology need to be engaged in the design research (Yarosh et al., 2011, p. 143). Our interest is not only in the implications of technology design for family connectedness but also in how design professionals can co-design with families to develop such technologies and what challenges can arise during the co-design process. In this review, therefore, we emphasise empirical research recording PDR and co-design approaches for informing and contributing to technology development.

The review by Isola and Fails (2012) does not concentrate on the theme of mediating family connectedness/communication but covers literature about approaches to designing technologies for families and their lifestyles, and analyses families’ roles of participation in technology design and summarises the related research themes from this literature. It reveals technology for distant family communication as a predominant theme in this field of participatory research and also identifies other themes related to technology for mediating family relationships and intimacy (Isola and Fails, 2012, p. 45). However, as drawn out by Isola and Fails (2012, p. 46), few studies have used participatory design methods with families, indicating the challenges involved, such as difficulty gathering families together in the same location for a certain amount of time and issues surrounding the power structures in families. Furthermore, although methods and tools used for engaging families as different roles are mentioned (Isola and Fails, 2012, pp. 43–44), there is no clear mapping of their interrelationships to inform methodological considerations in this research area.

Galleguillos and Coşkun’s (2020) review of participatory design practices for interaction design clearly lists the methods, stages of participant involvement, and research outcomes as well as the challenges involved. However, they mainly investigate PDR with less privileged groups, whereas our interest is in research that has engaged families as participants. They also confuse the concepts of methods and tools, putting them all in the category of ‘research methods’ (Galleguillos and Coşkun, 2020, p. 140). In the present study, we consider methods as activities of investigation conducted or facilitated by professionals in design research teams, with or without participants’ engagement, and tools as the instruments that have auxiliary functions in those investigatory activities. For instance, we consider analogue (non-digital) materials (Peters et al., 2021) and toolkits with digital/non-digital components (Sanders and Stappers, 2014a) as tools but co-design workshops with analogue materials or co-creation with digital materials as research methods.

Three gaps can be identified in the existing review studies in this field. First, review articles closely related to the themes of technology for family connectedness and co-designing with families for technology development are scarce, and there is no review article that considers both of these themes. Second, one of the review studies was conducted more than a decade ago (Isola and Fails, 2012). A more up-to-date review study that provides an overview of the intersection of these two themes is thus needed. Third, as there can be many generations with great age differences within one family, when considering mediating family connectedness, age/generational diversity can lead to differences in attitudes towards technology and in levels of familiarity and accessibility with different technologies (Plaisant et al., 2006; Ibarra et al., 2020; Bhowmick and Stolterman Bergqvist, 2023). Therefore, it is necessary to review the literature with families as research participants to explore practices from empirical studies as references to help the co-design of technologies for mediating family connectedness and the diverse and instructive needs and considerations for related technological design.

Research aim and questions

In this study, we aim to provide a review of empirical research on technology co-design with families for family connectedness to identify methods and tools of reference for co-design with families, the challenges of engaging families in design research for technological development, and the scenarios for and concerns related to mediating family connectedness by technology. We break down this research aim to the following four research questions:

1. What research methods and tools for co-design with families have been adopted in the research area of developing technologies for family connectedness?
2. What are the challenges of co-designing with families?
3. What are the scenarios that require technological mediation for family connectedness?
4. What concerns are there over mediating family connectedness by technology, and to what design strategies or principles do these lead?

By answering these four research questions, we seek to summarise the practical implications of co-design with families and the design implications of technological mediation for family connectedness to inform future design research and practices in this area. The next section justifies the key concepts of this review study, following which the methods of literature identification and analysis are described. Details on the extracted data, the review findings related to the research questions, and discussions

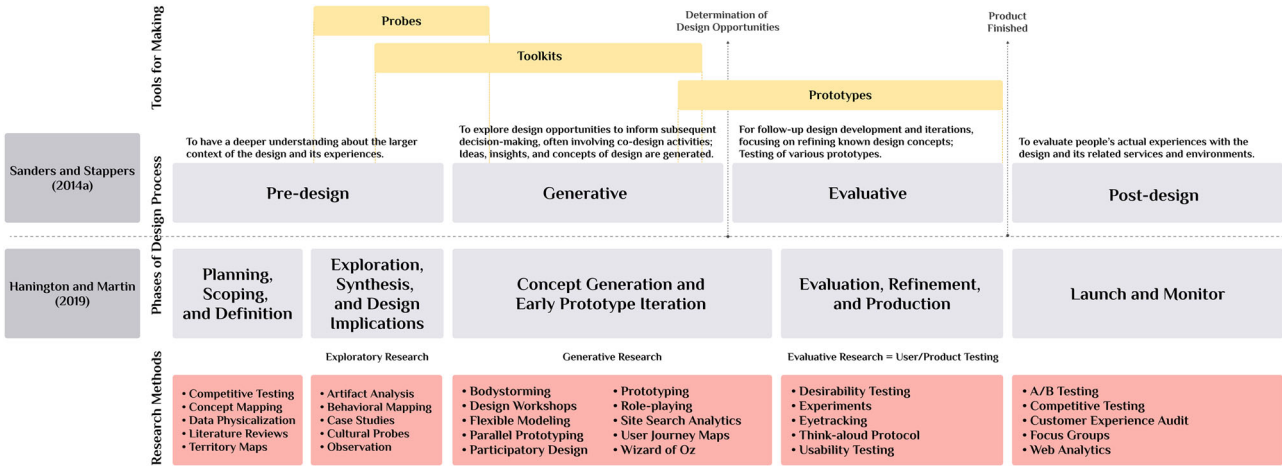


Fig. 1 Matrix displaying the design phases, research methods, and tools for making throughout the design process. Created by the authors.

of the key findings, limitations, and future research opportunities are then presented one-by-one, concluded by a summary of this review.

Related concepts

Family. There is no fixed definition of family agreed on in previous studies. Isola and Fails (2012) in their review define family loosely as ‘a unit of people that live in a home together or are related to one another’ (p. 46). Such a definition can gather somewhat more literature for analysis in a review but is too vague for the present study’s aim of analysing the methods and tools for co-designing with different families and the need for and concerns over the technological mediation of family connectedness.

To ensure the identified literature truly fits the research aim, we determine the scope of ‘families’ in this study to encompass (a) family members of generational or intergenerational kinships, such as sibling relationships, parent–child relationships, and grandparent–grandchild relationships, in traditional nuclear families, or the now common stepfamilies, single-parent families, or blended families; and (b) spouses in marital relationships (Eggebeen, 1992; Vetere et al., 2005; Matilda, 2023).

Co-design. There are various explanations of the concept of ‘co-design’. Some consider it as collective creative activities related to design among intradisciplinary or interdisciplinary experts, while others emphasise engaging people who are not trained in design but are to be served by the design throughout the design process to influence the decision-making (Sanders and Stappers, 2008, 2014b; Olesen et al., 2022; Galabo and Cruickshank, 2022). This study adopts the latter definition clearly stated by Sanders and Stappers (2008, pp. 6–7), considering co-design as the collaborative activity in design between designers or design researchers and those who are not design professionals.

Under such an understanding, the role of participants is no longer that of ‘users’ of a functional design, as in user-centred design, but rather that of co-designers who engage in creative activities that inform, ideate about, and conceptualise possible designs (Sanders and Stappers, 2008, p. 5). An important part of co-design practice is the making process of all collaborators during ideation, during which ‘people make artifacts and then readily share their stories about what they made or they naturally demonstrate how they would use the artefact’ (Sanders and Stappers, 2014a, p. 7). Through these complementary acts of ‘making, telling, and enacting’ (Sanders and Stappers, 2014a, p. 7) by participants, design researchers can determine a design direction with a better sense of the contextual information

behind the co-design ideas and how people would potentially like to interact with the designs.

Given our aim for a comprehensive review of the empirical studies on co-design with families, whether the participating families have engaged in informing new design possibilities, ideation, and design concept development and whether there is a co-making process with families are important criteria for our literature selection. The following detailed justifications of the concepts of co-design phases, corresponding research methods, roles of participants, and tools in co-design are significant as they help to construct the inclusion and exclusion criteria of literature and the analytic approach.

Phases, methods, and tools of co-design. Sanders and Stappers (2014a, pp. 10–11) divide the timeline of co-design into four phases: *pre-design*, *generative*, *evaluative*, and *post-design*. Hanington and Martin, in their book *Universal Methods of Design* (2012) and the updated version *Universal Methods of Design Expanded and Revised* (2019), also divide the design research process into phases, not four but five, according to which they mark the research and practice methods of design (Hanington and Martin, 2019, p. 11). The matrix in Fig. 1 visualises and compares how these authors define the phases of design research and the relevant methods and tools at each stage.

Hanington and Martin (2019) define the first phase of design as ‘planning, scoping and definition’ (p. 11), when the scope and elements of design are identified. In this phase, the design group usually conducts research activities such as literature reviews, gap analysis, concept mapping, creative matrix making, and initial exploratory approaches on people such as competitive testing, training, and observational shadowing to understand current insights about the existing brands, systems, services, or environments (Hanington and Martin, 2019, pp. 3–7), which are parts of the *pre-design* research (Sanders and Stappers, 2014a, p. 10).

The second phase in Hanington and Martin’s (2019) framework is ‘exploration, synthesis, and design implications’ (p. 11), which requires more immersive research and ethnography through exploratory research approaches into or with participants, aiming to explore possible design implications. This phase of design research from exploration to design implications in Hanington and Martin’s (2019) framework leads to the later generative research (pp. 11, 212) and can be considered as being at the intersection of Sanders and Stappers’s (2014a, p. 10) *pre-design* and *generative* research but still falling into the *pre-design* stage.

Table 1 Roles of participants in design research.			
Role	Phase(s)	Design research methods	Relationship with design professionals
User	Post-design	User Testing/Studies	Only participate after the design is done and released to the world.
Tester	Evaluative	Evaluative	Only participate during iterative testing of prototypes that have not been released to the world.
Informant	Pre-design; Generative; Evaluative	Exploratory; Generative; Evaluative	Relatively close relationship with design professionals, being engaged at critical points of the design and research process for inspiration.
Design partner	Pre-design; Generative; Evaluative; Post-design	Exploratory; Generative; Evaluative	Long-term, consistent, close partnerships with design professionals at various stages of the design and research process for the direct contribution of ideas.

Hanington and Martin’s (2019) third phase, ‘concept generation and early prototype iteration’ (p. 11), mainly includes participatory, generative research activities, especially co-design activities (pp. 238–239). However, *initial prototypes generation* is considered to be applied in the *generative phase* as a co-creation activity, often resulting in low-fidelity prototypes, whereas *prototype iterations* are normally conducted as part of *evaluative research*, with various fidelities of prototypes (Sanders and Stappers, 2014a, p. 9; Hanington and Martin, 2019, pp. 348–349; Isa and Liem, 2021, p. 332). As stated by Sanders and Stappers, the shift from the *generative* and *evaluative* phase occurs at the moment that a design opportunity is determined.

Furthermore, in Sanders and Stappers, (2014a, p. 11) framework, *probes* can be used in *pre-design* research and *generative* research and *toolkits* can be adopted from the late *pre-design* phase to almost the end of the *generative* phase. The research stage at which tools are adopted thus needs to be defined according to the research purpose, research methods, and research outcomes of a specific study.

The fourth phase in Hanington and Martin’s (2019) framework, ‘evaluation, refinement, and production’ (p. 11) matches perfectly with Sanders and Stappers’ *evaluative phase*. Finally, the *post-design* research phase (Sanders and Stappers, 2014a, pp. 10–11), or Hanington and Martin’s (2019) ‘launch and monitor’ phase (p. 11), is reached when the making of a final design product is complete, and it is ready to be released to the world for use.

In this review study, we mainly adopt Sanders and Stapper’s (2014b) four-phase co-design framework to identify empirical co-design research with families for devising technology for family connectedness. We also refer to Hanington and Martin’s (2019) framework to better identify methods and related tools for each co-design phase in the specific research area of technology design for family connectedness.

Roles of participants in co-design. For the roles of research participants, Sanders and Stappers (2014a, p. 8) only define ‘user as subject’ and ‘user as partner’. Druin (2002, p. 3) was the first to research the roles of participants in design research for technology development. However, as Druin’s study is focused on children and the dimension ‘relationship to adults’ (2002, pp. 2–3) is not applicable for identifying the roles of participants in general, we only refer to Druin’s descriptions of participants’ activities, stage(s) of participation, and what is to be studied to identify the different roles of participants.

According to Druin (2002, pp. 2–3), participants are engaged as *users* mainly by using the developed technology, when their interactions with the technology can be observed to explore the potential outcomes or effects. Participants as *testers* interact with and experience a not-yet-released technology (prototype) to provide feedback on their likes/dislikes and desired changes, which is important for further iterations (Druin, 2002, pp. 3, 7–9). Participants’ activity patterns are also investigated during testing

(Druin, 2002, p. 8). *Informants* and *design partners* can be engaged at various stages of research with similar research methods, ranging from the exploratory approaches at the early stage of design research through the generative approaches for informing or directly contributing to design ideas to the evaluative approaches during testing and refinement of design and even to research methods used when technology is developed (Druin, 2002, pp. 3, 10–18). The key difference between these two roles is when they engage in the design research process, which determines their proximity to the design research group. *Informants* are engaged at critical points when design professionals need inspiration for decision-making regarding the design direction (Druin, 2002, pp. 11–12), which is more in line with Galleguillos and Coşkun’s (2020) ‘research partners’, who are ‘[...] part of the analysis influencing decision-making about what to design’ and help ‘to determine which data are important to solving their problems’ (p. 142). In contrast, *design partners* participate throughout the design research process at a relatively constant frequency and for a relatively long period (Druin, 2002, p. 13).

Based on Druin’s (2002) classifications and descriptions of the roles of participants, Sanders and Stappers’ (2014a) framework of co-design phases, and the guidebook of design research methods by Hanington and Martin (2019), Table 1 below maps the correlations among four participant roles, four phases of co-design, three types of design research methods, and participants’ relationships with design professionals.

This mapping helps to classify the roles of families in co-design empirical studies and is hence beneficial to screening the literature for final analysis. According to Sanders and Stappers’ (2008, 2014a, 2014b) definition of co-design, which emphasises collaborative creation in design while acknowledging the different levels of creativity of participants (Sanders and Stappers, 2008, p. 12), and the challenge of maintaining participation over time (Galleguillos and Coşkun, 2020, p. 7), we include in this review design research in which families were involved as *informants* or *design partners* (Isola and Fails, 2012, p. 46) to devise technology for family connectedness together.

Interactive technologies. Given our interest in technologies for mediating family connectedness, research studies on interactive technologies that afford various types of interactions among family members are candidates for inclusion in this review. However, as we also explore co-designing technology with families, studies that are only about how people view or use existing (ICTs, such as mobile devices, interactive systems, or social media platforms that are already in use in the world, were excluded from consideration.

Moreover, we are interested only in digital, interactive technologies with tangible manifestations with which people can manipulate the world physically, based primarily on the claim of Ishii et al. (2012) that these are more suitable for human use because ‘humans have evolved a heightened ability to sense and

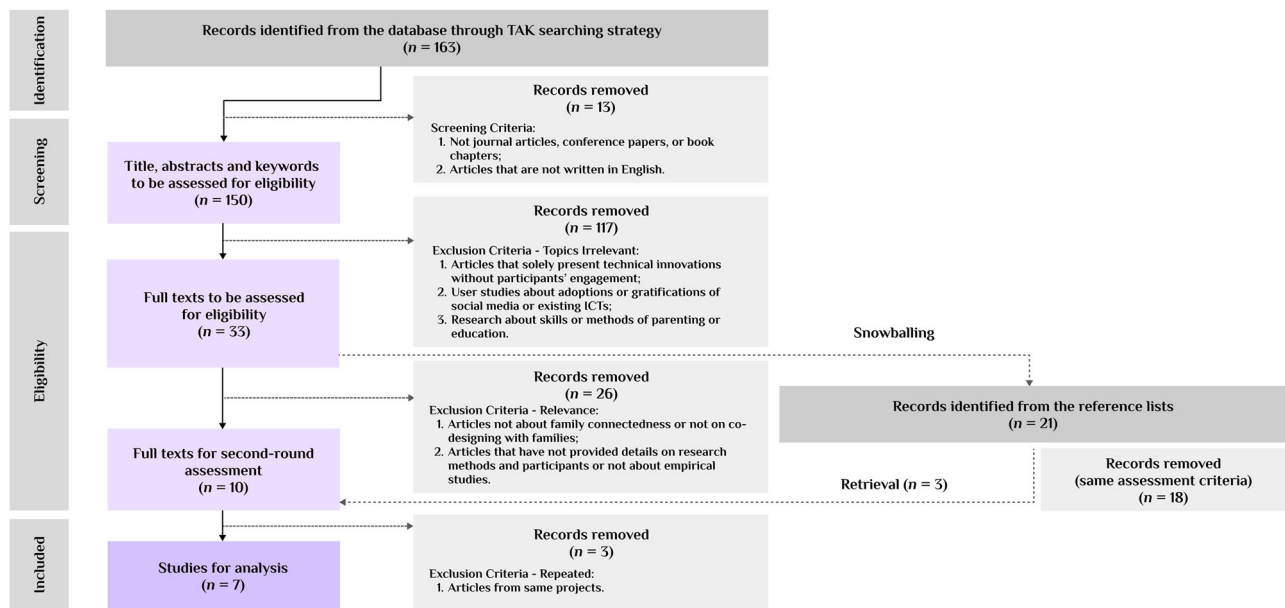


Fig. 2 Flowchart of literature identification, screening, and assessment. Created by the authors.

manipulate the physical world' (p. 38). Furthermore, previous studies highlight the significance of tangible elements to older adults whose overall mobilities are declining and hence find it difficult to interact with screen-only interfaces (Bhowmick and Stolterman Bergqvist, 2023) and to younger children who can hardly focus on the screen (Raffle et al., 2010). Therefore, interactive technologies that can only afford interactions through screens, requiring input from 'remote controls such as a mouse, a keyboard, or a touchscreen' (Ishii et al., 2012, p. 40), are beyond our consideration. Mobile games or massively multiplayer online games (MMOGs) (Tychsen et al., 2006) are thus not considered but play systems, such as pervasive games (Jonsson et al., 2006), that provide play experiences in a hybrid of the real and the digital worlds can be included.

Methods

Literature identification and screening. We performed a literature review to reveal the considerations about co-design methodology to engage families and insights into the needs for and concerns over the technological mediation of family connectedness. Terms and phrases related to the key concepts of 'family', 'connectedness', 'co-design', and 'interactive technologies' were used to identify literature in the Scopus academic database with a Title-Abstract-Keyword (TAK) search strategy.

Scopus was chosen as the sole database for identifying the literature because it is the largest multi-disciplinary academic database; its index of the content of over 23,700 peer-reviewed journals, books, and conference proceedings is much larger than other databases and digital libraries, the use of which could result in fewer or repeated results (Ibali, 2009; Ibarra et al., 2020). The literature included in Scopus covers a wide range of disciplines, from science and technology to the humanities and social sciences, that are considered closely related to co-design and technologies for connectedness (Ibali, 2009; Ibarra et al., 2020). We, therefore, extracted our initial pool of literature from Scopus but adopted a round of snowballing by screening the references of the identified literature when reading the full texts to minimise the influences of this limitation. The snowballed literature was subjected to the same inclusion and exclusion criteria as the literature identified from the database.

The rounds of literature screening and assessment were primarily conducted by the first and second authors and reviewed by the third author. The process is shown in Fig. 2. There were seven research articles finally included for review. An overview of the reviewed literature is presented in the 'Results' section below.

Review analysis. The review analysis was guided by the four research questions. To answer the first question about co-design methods and tools, we went through the details in the articles about how the authors planned and conducted their research. By surveying the descriptions of research participants and introductions to the purpose and rundowns of co-design research, we sought answers for the second and the third questions on types of family ties, co-design challenges, and scenarios of use. Answers to the fourth question about the needs and desires for technological mediation of family connectedness and the design implications were embedded in the research findings and discussions of the included studies. We report the outcomes of our analysis by themes in the Findings section below.

Results

Research that investigates co-designing technologies with families for their connectedness is limited, with only seven articles identified, as shown in Table 2, out of which two are journal articles, and five are conference papers (see the fourth column of Table 2). Four of these research articles were published in 2005–2010, and the other three articles were published in 2018–2019, with an 8-year gap of publications in between (see the third column of Table 2). This might be due to the rise since the late 2000s of smartphones, social media platforms, and other emergent technologies that afford co-located or remote communication (Harper, 2010; Greenfield, 2018), leading research attention towards topics such as how media technologies influence social behaviours or why people use these media technologies (Sagoo and Rhee, 2006; Biemans et al., 2009; Wei, 2013; Whiting and Williams, 2013; Sherman et al., 2013; Stuedahl and Lowe, 2014).

Of the seven included articles, almost all were conducted in Western contexts, except for one in India (see the fifth column of Table 2), indicating a lack of insights from regions outside of Western countries, which has the potential to bias the analytical

Table 2 Overview of the reviewed literature.				
Research item (title)	Author(s)	Year	Item type	Context (country/region) ^a
<i>Mediating Intimacy: Designing Technologies to Support Strong-Tie Relationships</i>	Vetere et al.	2005	Conference Paper	Australia and Denmark
<i>Shared Family Calendars: Promoting Symmetry and Accessibility</i>	Plaisant et al.	2006	Journal Article	Sweden, France, and the United States
<i>Video Play: Playful Interactions in Video Conferencing for Long-Distance Families with Young Children</i>	Follmer et al.	2010	Conference Paper	Canada and the United States
<i>The Family Window: The Design and Evaluation of a Domestic Media Space</i>	Judge et al.	2010	Conference Paper	Canada and the United States
<i>Participatory Design for Creating Virtual Environments</i>	Raju	2018	Conference Paper	Mumbai, India
<i>Together Together: Combining Shared and Separate Activities in Designing Technology for Family Life</i>	Christensen et al.	2019	Conference Paper	Denmark
<i>Storywork in STEM-Art: Making, Materiality and Robotics within Everyday Acts of Indigenous Presence and Resurgence</i>	Tzou et al.	2019	Journal Article	The United States

^aContexts were identified from the authors' descriptions of the scope of their study and the research participants and from the authors' affiliations.

outcomes. However, considering the European origin of participatory research and co-design and its social-political background related to civic rights movements (Sanders and Stappers, 2008; Robertson and Simonsen, 2012), it is understandable that most of the research has taken place in Western countries and regions.

We extracted from each article the research methods, tools for engaging families and for actualising or refining design ideas, and descriptions of the research participants (Table 3). In each study, at least one family participates at different stages of the design process to provide critical ideas and feedback that could inform further design development and iterations. In five (Vetere et al., 2005; Plaisant et al., 2006; Raju, 2018; Christensen et al., 2019; Tzou et al., 2019) of the seven included studies, families participated not only in multiple phases of design research but also in various co-creation activities to inform or directly contribute to design ideas. Therefore, we considered these studies as co-design research according to the definitions of co-design as involving participants being engaged as ‘co-designers’ Sanders and Stappers’ (2008, pp. 6–7) or ‘informants’ and ‘design partners’ (Druin, 2002) to inform, ideate, and conceptualise designs.

Six kinds of family ties (Eggebeen, 1992; Matilda, 2023) appear in the included literature. In three studies (Follmer et al., 2010; Christensen et al., 2019; Tzou et al., 2019), the participants are parents and children. One study (Raju, 2018) involves a close partnership with a grandparent and grandchildren. Two other studies (Plaisant et al., 2006; Judge et al., 2010) engage multi-generational families as participants, with the families composed of three generations, including a junior nuclear family of parents and children and one or two extended families of grandparents. In one of these two studies (Judge et al., 2010), there is a multi-generational family in which the extended family on the maternal side is a stepfamily. There are also generational family ties between siblings (Judge et al., 2010) and between spouses (Vetere et al., 2005).

We found only five studies that define the families’ roles of participation in design research (see the second column of Table 4). Although all the included research items are considered co-design research, four of them (Vetere et al., 2005; Follmer et al., 2010; Raju, 2018; Christensen et al., 2019) identify families as ‘users’. Only one study (Plaisant et al., 2006) correctly positions the participating families as design partners. This suggests a lack of epistemic understanding about co-design and the roles of participants in empirical design research.

Looking at the design outcomes and design concepts (the fourth and fifth columns of Table 4) together, there are five designs for remote family connectedness, which are digital or digital-physical hybrid technologies affording mutual awareness and presence (Vetere et al., 2005; Judge et al., 2010), family

information sharing (Plaisant et al., 2006), or shared storytelling (Follmer et al., 2010; Christensen et al., 2019). The designs in the other two studies are directly co-created with or by the participating families as representations of family stories (Raju, 2018; Tzou et al., 2019). There are a total of four co-design research projects about family storytelling among the included studies.

The data explored in this section provides a general sense of where and how research has been conducted, who the ‘families’ are and what roles they play in research, and what design outcomes can be generated in this specific research area related to technology-mediated family connectedness. In the next section, we present the findings of our review analysis and attempt to answer the proposed research questions.

Findings

Methods and tools for co-designing with families. As justified in the ‘Introduction’ section above, we use ‘methods’ to refer to research activities and ‘tools’ to refer to the auxiliary instruments for assisting the investigatory activities, especially the materials and components for creative activities. Furthermore, as defined in the Phases, Methods, and Tools of Co-Design section, *design implications* are found at the intersection of *pre-design* research and *generative* research; *design ideas and concepts* are determined at the point between *generative* research and *evaluative* research; and the launch of a finalised *design product* marks the end of *evaluative* research and the start of *post-design* research (Sanders and Stappers, 2014a; Hanington and Martin, 2019).

Accordingly, in Table 5, we map the methods used in each study with the co-design phases according to the purposes and outputs of the research activities. Three studies record pre-design research, five studies record generative research, and five studies record evaluative research; none of the studies record post-design research. Overall, in the field of co-designing technology with families for mediating their connectedness, there is limited pre-design research about/with families, and the methods adopted for this are also limited. There are more diverse generative research methods, including various forms of participatory design (PD)/co-design workshops, technology probes, and idea testing with initial prototypes, supported by methods such as interviews, observation, and data logging. Prototype testing and deployment are the main evaluative methods in co-design research, accompanied by data logging and follow-up interviews and questionnaires.

Interviewing, which is a fundamental research method that can help to extract insights directly from participants (Hanington and Martin, 2019, pp. 280–282), is the most widely adopted research method in co-designing with families. It is adopted in six of the

Table 3 Research design of the reviewed literature.

Research Item	Method(s) ^a	Tool(s) ^b	Participants
Vetere et al., 2005	1. Home visit	/	6 pairs of cohabitating heterosexual Caucasian couples in stable relationships (3 pairs with children) aged from their late 20s to late 40s
	2. Cultural probes (7 weeks); Periodical interviews (3 times)	Diaries, scrapbooks, camera with docking printer, postcards, pens, glue, scissors, catch-phrase stickers; small, printed facsimiles of mobile device screens	
	3. Focus group	/	
	4. Brainstorming and design workshop	/	Human-computer interface experts
	5. Participatory design workshops (4 weeks)	Tools for drawing; pictures taken from cultural probes, etc.	The 6 pairs of couples participated in Stages 1–3
	6. Prototyping	/	/
Plaisant et al., 2006	1. Interviews	/	3 Swedish families; 3 French families; 1 U.S. family
	2. Cultural probes	Disposable cameras, diaries, and post-it notes	
	3. Technology probes ^c ; Data logging; Subsequent interviews	2 technology probes: messageProbe and videoProbe	
	4. Full-day workshops: Low-tech prototyping activities (with individual households, entire families, and multiple families)	Low-tech materials	Online respondents The U.S. family (same as in Stages 1–4): Junior family parents and 2 children (aged 10 and 13) and two households of two sets of grandparents
	5. Online web survey (~ 2 months)	Online questionnaire	
	6. Case study: Interviews (each household)	Early paper prototype	
	7. Field study: Prototype deployment (8 months); Home visits; Informal interviews; Screen captures	Functional prototype: Shared Calendar	
	8. Design iteration	/	
Follmer et al., 2010	1. Lab trials; Observation; Interviews	Prototypes: Find It; Farmer's Animals	/
	2. Lab-based experiment	Prototype: Story Places	
	3. Lab-based testing; Data logging; Interviews	Prototype: People in Books (Building on findings from stage 1)	
Judge et al., 2010	1. Pilot study (4 months)	Initial prototype	The <i>researcher's family</i> : The household of a researcher, his wife, and 2 children (aged 3 years and 8 months), and the household of the researcher's parents The <i>sisters' families</i> : The household of Sister 1 and her husband and son (aged 18 months), and the household of Sister 2 and her partner; The <i>daughter's family</i> : The household of a daughter, her husband and son (aged 2), and the household of the daughter's mother and stepfather
	2. Long-term field deployment (4 months); Semi-structured contextual interviews (4 times)	Updated prototype	
	3. Short-term field deployment (5 weeks); Semi-structured contextual interviews (4 times)		
Raju, 2018	1. Exposure to head-mounted display and physical model of the house; Writing/drawing desires and fantasies	Books and pens	A grandmother (aged 61), her granddaughter (aged 11), and her grandson (aged 8)
	2. Home visit; Co-making wish list for virtual home (grandchildren)	/	
	3. Co-making imaginative artifact: Pegasus and a chocolate tree	Plasticine and paper, a chocolate tree using Styrofoam, acrylic colours	
	4. Ideas actualisation: 360-degree video recording	The house model and the co-made artifacts	
	5. Home visit; Additional ideas co-creation	/	
	6. Additional ideas actualisation	Physical setup; Necessary raw materials (Styrofoam, gum, acrylic colours etc.); Video recording equipment	
	7. Final prototype display	Co-created outcomes	

Table 3 (continued)

Research Item	Method(s) ^a	Tool(s) ^b	Participants
Christensen et al., 2019	1.1. Provotype ^c Activity #1 – Shared Calendar co-creation	A3 paper, cards representing different technologies, blank cards	Family 1: Mother (46), father (40), two daughters (12, 9), and a son (12); Family 2: Parents (both 41) and two sons (11, 9); Family 3: Mother (47), father (46), a daughter (9), and a son (7)
	1.2. Provotype ^c Activity #2—Social Drawing co-creation	Paper and pens	Family 4: Mother (46), father (44), two sons (9, 5) and a daughter (7); Family 5: Mother (45), father (44), two daughters (14, 10), and a son (7); Family 6: Parents (both 43) and two sons (13, 8)
	2. In-situ evaluation: Prototype deployment; Interviews; Questionnaires	Prototype: STORIES	Families 2 and 4
Tzou et al., 2019	1. Brainstorming: Family story co-creation; Observation	Three prompts: past family experience; a-decade future speculation; an important place to the family	The Pony Family: 2 parents and a daughter (aged 7) who are Seneca-Cayuga; The Wanbli family: 2 parents and 2 sons (aged 13 and 10) who are Lakota and Paiute
	2. Co-Design: Animating family story; Observation	Robotics elements such as motors, LED lights, and sensors; Scratch (programming platform)	
	3. Co-Design: Scene building a diorama in a cardboard box; Observation	A diorama in a cardboard box	
	4. Final Presentations	Co-created outcomes: Dioramas	
	5. Post-workshop interviews	/	

^aMethods were extracted from the authors' descriptions of their research and design activities, regardless of whether there was participant involvement.

^bTools record only the instruments adopted in each study for engaging families and actualising or refining the design ideas co-created by families.

^cNew design research method proposed by the projects.

Table 4 Roles of families, design outcomes, and design concepts in the reviewed literature.

Research item	Roles of families—defined by author(s)	Design outcome	Design concept
Vetere et al., 2005	Users	Smart clothes: <i>Hug Over a Distance</i>	For initiating, reciprocating, or rejecting remote hugs between intimate partners
Plaisant et al., 2006	Design Partners	Digital, layered interface: <i>Shared Family Calendars</i>	For the symmetrical sharing of calendar information among remotely located, multi-generational family members
Follmer et al., 2010	Users	Shared book-reading, video play activity: <i>People in Books</i>	For superimposing remote family members as virtual characters in a shared e-book for storytelling
Judge et al., 2010	N/A	Domestic Media Space: <i>Family Window</i>	For connecting remote households through an always-on video media space
Raju, 2018	Users	Virtual home	For intergenerational storytelling to invoke the feeling of 'Home'
Christensen et al., 2019	Users	Interactive, digital-physical hybrid technology: <i>Stories</i>	For shared and separate storytelling among family members in both co-located and remote contexts
Tzou et al., 2019	N/A	Robotic dioramas	For family storytelling and for indigenous presence and resurgence

studies (excepting only Raju, 2018) and can be adopted in the pre-design, generative, and evaluative phases as a stand-alone research method to understand families' real-world experiences or as a supportive method for getting follow-up insights on design from other research activities in the co-design process. The studies of Vetere et al. (2005), Plaisant et al. (2006), Judge et al. (2010), and Christensen et al. (2019) use contextual interviews in the domestic environment, whereas the families in the studies of Follmer et al. (2010) and Tzou et al. (2019) are interviewed in studio settings following lab-based testing or co-design workshops. Home visits can also be adopted across the pre-design, generative, and evaluative research phases to attain a better understanding of the domestic environments of the engaged families, the contextual environment of the design, and how the families use the technologies in real-world settings (Vetere et al., 2005; Plaisant et al., 2006; Raju, 2018).

PD or co-design workshops can theoretically also be adopted throughout the pre-design, generative, and evaluative phases of design research according to research needs (Hanington and Martin, 2019, pp. 330–331). In the included studies, PD or co-design workshops are mostly adopted in the generative phase of co-design research, with four studies using these workshops to engage families in various forms of creative activities for ideation. Activities for PD and co-design workshops at the generative stage range from brainstorming to ideas co-creation to low-tech prototyping and artifact co-making. A PD workshop also appears as a pre-design research method in the study of Christensen et al. (2019), in which the authors propose two 'provotype' activities to provoke families to co-create shared artifacts that can inform possible designs of technologies for inducing connectedness and togetherness in remote and co-located families.

Table 5 Methods adopted in each co-design phase in the reviewed literature.

Research item	Pre-design research	Generative research	Evaluative research
Vetere et al., 2005	Home Visits Cultural Probes Interviews Focus Group	Participatory Design Workshops (Ideas Co-Creation) Prototyping	/
Plaisant et al., 2006	Interviews Cultural Probes	Technology Probes Data Logging Interviews Participatory Design Workshops (Low-Tech Prototyping) Online Web Survey	Prototype Deployment Home Visits Interviews Data Logging (Screen Capture) Design Iteration
Follmer et al., 2010	/	Lab-Based Idea Testing Observation Interviews	Lab-Based Prototype Testing Data Logging (Videotapes; Screencasts) Interviews
Judge et al., 2010	/	/	Prototype Deployments Design Iteration Interviews
Raju, 2018	/	Co-Design Workshops (Studio-Based Brainstorming; In-Situ Artifact Co-Making; In-Situ Ideas Co-Creation) Prototyping Home Visits	/
Christensen et al., 2019	Participatory Design Workshops ('Provotype' Activities)	/	Prototype Deployment Interviews Questionnaires
Tzou et al., 2019	/	Co-Design Workshops (Brainstorming; Artifacts Co-Making) Observation	Presentations Interviews

Referring to Table 3, the tools supporting PD/co-design activities are usually low-tech art materials that are plain or shapable. However, in the study of Raju (2018), the grandmother and her grandchildren are exposed to VR helmets and 360-degree video, which they later use to co-create footage of a virtual home based on other low-tech prototypes they have made for family storytelling. Furthermore, in the study of Tzou et al. (2019), digital, robotic materials are applied together with cardboard and other art materials for family co-designing. Whether these technologies and materials can be further applied in other projects related to co-designing with families is unclear and requires further empirical exploration.

Cultural probes are mainly adopted in pre-design research as tools for exploratory research; they also represent an exploratory research method in design (Gaver et al., 1999; Hanington and Martin, 2019, pp. 132–133). Cultural probes are provocative instruments comprising any kinds of things that can provoke participants' self-understanding and record their everyday encounters (Hanington and Martin, 2019, p. 132): pens, notebooks, papers, printouts, cards, cameras, and so on (see Table 3). The families engaged in the studies of Vetere et al. (2005) and Plaisant et al. (2006) are given cultural probes to reflect on their daily interactions with intimate partners or with other family members and their adoption of technologies in their everyday family communication. In contrast, technology probes, which are instruments that afford the simplest technological functions to be evaluated, are proposed for adoption at the beginning of generative research (Hutchinson et al., 2003; Plaisant et al., 2006). Technology probe deployment represents the investigatory method, in which families examine ideas about technology design for family communication in actual domestic contexts. The application of cultural probes and technology probes in the included studies coincides with the suggestion in the framework of Standers and Stappers (2014a, p. 11) that probes can be applied in pre-design and early generative research.

Prototypes are often generated by design professionals at the end of the generative stage and then tested in studio settings (Follmer et al., 2010) and/or deployed in the field and used for a period of time by participating families (Plaisant et al., 2006; Judge et al., 2010; Christensen et al., 2019) to test whether the prototype can actually mediate the feeling of connectedness among family members. The method of data logging is used to support technology probe deployment and prototype testing/deployment by capturing the content and actions generated by the families as they use the technology (Plaisant et al., 2006; Follmer et al., 2010).

Like interviews, focus groups, online surveys, and questionnaires are fundamental research methods that are not commonly used in the included studies but can be adopted as needed to collect necessary information related to the design, such as desires related to remote family coordination (Vetere et al., 2005; Plaisant et al., 2006) and families' opinions on the designed prototype (Christensen et al., 2019). Observation is not adopted as an exploratory research method at the beginning of design research but sometimes serves as an element of research triangulation to investigate families' interactions mediated by the devised prototypes of potential technologies (Follmer et al., 2010) or families' actions throughout the co-design process (Tzou et al., 2019).

Challenges in co-designing with families. The limited results of the literature identification and screening somewhat indicate the difficulties of co-designing with families. The lack of research covering all four phases of co-design also suggests challenges in long-term partnerships with families in the co-design of technology. In Table 6, we list the phases of families' engagement in each research study, according to which we revise the roles of families in design research of the included studies (see the second and third columns). The family ties of

Table 6 Revised information about families' engagement in the co-design research.			
Research Item	Phase(s) of engagement	Role of families—revised	Family ties of participants
Vetere et al., 2005	Pre-design	Design Partners	Intimate couples and spouses
Plaisant et al., 2006	Generative	Design Partners	Multi-generational family
	Pre-design		
Follmer et al., 2010	Evaluative	Informants	Parents and children
	Generative		
Judge et al., 2010	Evaluative	Informants Testers ^a	Multi-generational family Siblings ^a Multi-generational family with extended stepfamily ^a
	Evaluative		
Raju, 2018	Generative	Design Partners	Grandparents and grandchildren
Christensen et al., 2019	Pre-design	Informants	Parents and children
	Evaluative		
Tzou et al., 2019	Generative	Design Partners	Parents and children
	Evaluative		

^aThese families are engaged in one-shot, short-term evaluation, hence taking the role of testers.

participants actively engaged in the research are presented in the last column of the table.

Five studies mention challenges in co-design research related to participant recruitment and findings generalisation. As the studies of Plaisant et al. (2006) and Raju (2018) engage only one family for long-term collaboration, the research could be biased and the possibility of generalising the research outcomes to other contexts and populations is limited. A similar issue is reported in the study of Judge et al. (2010), in which limited diverse families are engaged in long-term prototype deployment. The studies of Vetere et al. (2005) and Christensen et al., despite engaging more families, also report potential issues in research generalisation regarding family demographics and diversity.

Although design professionals may have strong intentions to recruit more families for a long-term partnership, as indicated in the study of Plaisant et al. (2006), there are many challenges related to time scheduling, technical issues, and potential changes/updates. If the research involves multiple households, it is common to face networking and software configuration problems across multiple households and devices, and there are difficulties involved in debugging and troubleshooting emergent issues with the design remotely without physical access (Plaisant et al., 2006, pp. 335, 341–342). Similarly, Judge et al. (Judge et al., 2010, p. 2363) encounter latency of responses in actual deployment due to unstable home Internet connections. Regarding time scheduling for research activities, especially for regular check-ins, it is difficult to accurately estimate the time needed for software installation and upgrades, and family members could have busy and diverse schedules, all of which can result in delays in the research progress (Plaisant et al., 2006, pp. 335, 341–342). The demand for renewal may also lead to reluctance or irritability in some families, which can lead to an inability to collaborate in the research (Plaisant et al., 2006, p. 335).

Raju (2018) indicates difficulties in setting free the imagination and creativities of families. Excluding families from the initial physical model until late in the process restricts their reflections on their aspirations and lived experiences (Raju, 2018, p. 66). It is also difficult for families to generate design ideas if there is no specific goal of design in mind.

However, there is no significant correlation in the reviewed studies between the revised roles of families in co-design research and the family ties of research participants. There is only an indication that partnering with families of multiple households can lead to difficulties in co-design research. What is certain is that engaging multiple families for a long time across all phases of

research to co-design technology for family connectedness is currently not practised, and its feasibility requires further exploration.

Scenarios of technology-mediated family connectedness.

Referring to the design concepts of the included studies listed in Table 4, scenarios of technology-mediated family connectedness can be determined based on distance (co-located/remote), synchronicity (shared/separate, synchronous/asynchronous), and types of family ties (the six types as presented in Table 6). As summarised in the ‘Results’ section above, five of the reviewed studies are about remote family connectedness and two about directly co-creating physical or virtual representations of family stories (Raju, 2018; Tzou et al., 2019). We can draw from this that most designs attempt to address the separation of families to mediate connectedness between two or more remote/distributed family members.

Among the five designs for mediating remote family connectedness, four afford real-time presence and awareness through various channels. The design in Vetere et al. (2005) mediates the intimacy and mutual awareness of remote couples/spouses through smart clothes that can inflate or release to imitate hugs. Judge et al. (2010) devise a media space for remote domestic sharing through which remote households can always be aware of what the other side is doing through a video screen, hence generating a feeling of connectedness. Similar to providing a media space for perceiving mutual existences, the designs of Follmer et al. (2010) and Christensen et al. (2019) create virtual shared contexts for remote parents and children to feel togetherness. Follmer et al. (2010) adopt a video feed for projecting actual images of parents and children into the same virtual scenarios in a video conferencing system, and Christensen et al. (2019) make use of avatars to represent the separated parents and children in the virtual space.

However, real-time presence and awareness through shared activities or synchronous information sharing are not always required for family connectedness. The study of Plaisant et al. (2006) reveals the grandparents’ satisfaction in just knowing the updated schedules of their adult children and grandchildren. There is a consensus among members of the engaged family that everyone has different schedules and that the children and parents in the junior family are always busy (Plaisant et al., 2006, p. 327). Sharing and keeping records of schedules is already satisfactory for maintaining a certain

connection with family members without disturbing each other (Plaisant et al., 2006, p. 327). Furthermore, as the grandparents cannot handle complex designs, it is sufficient to provide them with something simple and easy to manipulate (Plaisant et al., 2006, p. 328). As for the design by Christensen et al. (2019), it not only affords real-time, shared activities for feeling togetherness but also separate contributions to a single story.

Unlike the other projects, the research by Raju (2018) and Tzou et al. (2019) involves trying to create a sense of family connectedness throughout the process of co-design. In these two studies involving imaginative storytelling, family members of different generations co-create a family story together and present it with high-tech instruments and low-tech materials. The outcomes of their designs are technological but physical, representing not only the family's co-made story but also the connectedness among those who made it. This is consistent with previous studies on co-design indicating the influences of the co-design process on participants' well-being.

From these findings we can conclude that mutual awareness can support family connectedness but also that the shared effort itself can facilitate a feeling of being connected with family members (Hassenzahl et al., 2012, p. 6). This is applicable to the remote context and co-located experiences and to diverse types of family ties.

Concerns over mediating family connectedness by technologies

Privacy and self-disclosure. Privacy concerns surround designs involving video camera installations, given the amount and contents of the information disclosed. Even between two households of a family, such installations can cause discomfort over being watched unintentionally, and people have different comfort levels in switching between watching and being watched (Judge et al., 2010, p. 2368). People can feel unsafe without the autonomy to decide what and how much to disclose, highlighting the significance for alleviating stress of allowing control over disclosure by offering options of access to content on both sides (Judge et al., 2010, pp. 2368–2369). Wearable technologies that are closely attached to human bodies to simulate intimate acts also arouse privacy concerns; as 'intimate acts often entail self-disclosure' (Vetere et al., 2005, p. 472), they present challenges related to privacy. Providing control over what to share also works in this design context (Feijt et al., 2021). However, as Feijt et al. (2021, p. 4) suggest, subjective experiences and perceptions must also be considered to fully comprehend the impact of technology-simulated sensory experiences on our social interactions. Small individual differences may also affect people's feelings about the same design and ultimately hinder their willingness to adopt.

Tangible designs. Although previous research has suggested that tangible technologies bridging the physical and the digital are more likely to meet the needs of easy manipulation, given our ability of eye-hand coordination, and hence to achieve higher levels of acceptance (Yarosh et al., 2011; Ishii et al., 2012; Bhowmick and Stolterman Bergqvist, 2023), the included studies rarely have tangible designs as output. It is sometimes unrealistic to pursue only tangible design, considering people's familiarity with existing patterns, children's attention spans, and constraints of space, equipment, and cost. This insight can be seen clearly from the study of Follmer et al. (2010), who evaluate intangible and tangible prototypes with families but return to the intangible design after iteration. Follmer et al. (2010) admit that tangibles can facilitate communication, thinking, and creativity but also point out that children engaging with the tangibles 'lacked the ability to share their state with remote parties' (p. 56).

Follmer et al. (2010) indicate that the key to generating a sense of family togetherness is to create a shared context and support shared activities building on the existing play patterns of children and other family members. They, therefore, scaffold collaborative storytelling between young children and adult family members and playful interactions through video conferencing to mediate remote family connectedness. Similar insights and practices can be found in the study of Christensen et al. (2019).

Nevertheless, this does not mean that tangible designs are not beneficial at all. For older adults and young children especially, leveraging familiar forms, tools, and real objects that they have been living with can facilitate acceptance of technologies. Plaisant et al. (2006, p. 330) investigate the use of a digital pen and digital paper to create a sense of familiarity for older adults in the family, with the older adults finding it too complex to understand and manage the digital notifiers (Plaisant et al., 2006, p. 328). Familiarity and simpleness are hence the topmost concerns in devising technologies for manipulation by diverse age groups. Embedding technologies that can detect real objects to interweave the virtual and the real and the tangible and the intangible while not requiring the exposure of sensory or other private information might be a feasible approach (Follmer et al., 2010, p. 56).

Playful collaborations. We touch on playful collaborations above in discussing shared activities between parents and children. Four of the included articles provide common insights related to mediating the family connectedness between young children and other adult family members in a playful, collaborative way, which involves scaffolding storytelling with other interactive, shared activities that children consider interesting and fun while feeling being connected with other family members.

However, a concern related to technologies designed to afford playful collaborations is different perceptions of playfulness. Play activities for children may not be as interesting to adults, and perceptions of playfulness vary by age. Extra considerations are required to encourage adult family members to let go while making the difficulty and playfulness of content and activities suitable for both children and adults (Eriksson, 2010, p. 345; Follmer et al., 2010, p. 52).

Discussion

Key findings. According to our review analysis, the empirical research on co-designing technologies with families for connectedness is limited, with only seven studies identified in thus 2005–2019 period. As most of this research was conducted in Western contexts, there is a particular lack of research insights from other countries and regions.

All the included studies involve families in multiple phases of the design process and co-creation activities, demonstrating co-design according to the definition of Sanders and Stappers (2008, 2014a). A range of methods are used, including interviews, cultural probes, technology probe deployment, PD or co-design workshops, and prototype testing or deployment. Interviews are adopted most widely and most frequently in various design phases, and PD/co-design workshops and prototype testing/deployment are also often applied in the generative and evaluative phases of research, respectively.

We identified four challenges of co-designing with families from the literature, which make it difficult to engage families as close design partners. First, engaging families for long-term, sustained participation throughout the entire co-design process is challenging due to scheduling conflicts and potential changes over time (Plaisant et al., 2006). Therefore, maintaining the consistent involvement of families is challenging. Second, most of the studies involve small sample sizes, suggesting difficulties in

recruiting a large and diverse sample of families that represents different demographics and limiting the validity and generalisability of the research findings (Vetere et al., 2005; Plaisant et al., 2006; Judge et al., 2010; Follmer et al., 2010; Raju, 2018; Christensen et al., 2019). Third, even if a sufficient number of families from diverse demographic and cultural backgrounds were to be recruited, technical difficulties such as network instability and software configuration problems can arise when the co-design involves multiple remote households and devices (Plaisant et al., 2006; Judge et al., 2010). Research may be delayed by these problems, which can also strongly reduce participants' willingness for continuous engagement. Finally, there are challenges in co-design activities related to setting free the participants' imaginations and creativities. Family members, and especially children, need prompts and goals for stimulating creative ideas (Follmer et al., 2010; Raju, 2018).

The designs in this area include those exploring video conferencing, shared calendars, virtual environments, and making activities, revealing the need for mediating connectedness across distance and generations. The reviewed studies investigate the mediation of connectedness in a variety of family ties, including parent-child, grandparent-grandchild, multi-generational, and spousal relationships. There are no obvious correlations between the family ties and ages/generations of the engaged participants and the roles of participants in design research, but these can affect decisions addressing concerns related to tangible designs and the playfulness of shared activities. Privacy and self-disclosure concerns centre around the amount and type of information disclosed through video cameras or direct sensory experiences without controls to permit autonomy (Vetere et al., 2005; Judge et al., 2010). The studies further indicate that technologies designed to be manipulated by young children and older adults need to leverage familiar tangible objects (Plaisant et al., 2006; Follmer et al., 2010) and that technologies affording playful interactions face differing perceptions of playfulness by age, thus requiring a balance between children's interests and adult engagement through shared activities such as collaborative story making and collective storytelling (Follmer et al., 2010; Raju, 2018; Christensen et al., 2019; Tzou et al., 2019). The needs and concerns regarding technologies for mediating family connectedness require further attention, given the changing family structures and ages. The potential influences of the co-design process with families on family connectedness are also worthy of further exploration.

Implications for future co-design research with families. Given the research gaps in this specific area, the methods and tools adopted for co-designing with families, and the challenges of co-design research in this context, there is a range of possible future empirical research related to co-design with families. One promising research direction is to explore flexible co-design methods that allow consistent yet accommodating participation regardless of scheduling issues or life changes over a long research duration. Social mobility and mobile sociality are salient phenomena in modern cities (Latham and Layton, 2019; Chen and Lunt, 2021), in which people travel everywhere at a fast pace, connect with those close to them using mobile devices, and are usually busy and have highly spontaneous schedules. The requirement of a flexible time schedule is both a potential challenge and a good research opportunity for co-design exploration.

The present review reveals a lack of empirical research engaging multiple families with diverse backgrounds as design partners for long-term co-design research. Furthermore, the empirical studies in related fields are limited in number and concentrated in Western countries and regions. Follow-up research can consider

recruiting participants from diverse backgrounds through cross-cultural research collaborations or other not-yet-adopted methods to contribute valuable insights. Future empirical research may also explore innovative tools for conducting co-design research with families. Emergent technologies such as metaverse platforms can be trialled to facilitate co-design activities online (Volk, 2008; Xu et al., 2022; Shatilov et al., 2023) and AI technologies (Bratteteig and Verne, 2018) can be explored to help families actualise their design ideas in co-design sessions.

Design implications for domestic communication technologies. Based on the key findings from the literature and related theories that we refer to in this review study, we summarise six design implications for the investigation and development of domestic communication technologies:

1. Co-design technologies with large and diverse samples of families and experts in related fields;
2. Build on existing patterns of shared activities between family members, such as storytelling, calendar coordination, and co-making activities, to devise technologies to mediate connectedness across distances and generations;
3. Balance the interests of children and adults when considering affording playful interactions, as perceptions of playfulness can vary greatly by age;
4. Leverage familiar, everyday, tangible objects in domestic settings that are easy to manipulate for young children and older adults to facilitate the acceptance of and engagement with new technologies;
5. Afford autonomy by offering individuals control over what and how much content to disclose when implementing technological components such as cameras or sensors, to respect various privacy needs and preferences;
6. Continue to explore the changing needs for family connectedness as family structures evolve and the ages of family members changes and to investigate how co-design processes involving families can in themselves further strengthen technology-mediated family ties.

These six implications are not rigid guidelines for technological designs in this area. Instead, we hope that this summary of the implications for technological designs can help design practitioners at the intersection of communication, social science, and technology to fully consider the opportunities and risks of design for family connectedness and thus avoid harmful designs (Monteiro, 2019) and make a positive contribution to society.

Limitations. There are some limitations in this review. First, only one academic database, Scopus, was used for literature identification. Although its coverage is large, it is possible that relevant research from other databases or sources may have been missed. We identified additional relevant research by screening the references of the literature identified from Scopus search results to minimise the influence of this limitation.

Second, due to the language barrier, the review only includes English publications, introducing a potential language bias. We acknowledge that despite English being a global language for academic research, it is valuable to include literature written in other languages. This might also partly explain why most of the included empirical studies were conducted in Western cultural contexts. This limitation again stresses the importance of cross-cultural collaboration in academic research, which we will pursue in future work.

Third, as our focus was on research investigating co-design with families, studies in which families participated at lower

engagement levels were excluded from the review. This decision of scope is highly related to the definition of co-design given by Sanders and Stappers (2008, 2014a) but might have led to valuable insights being missed. The small number of samples also makes it difficult to provide a quantitative synthesis of the findings on research designs across the included studies.

In summary, this review provides an overview on co-designing technologies with families for connectedness but its findings should be considered within the constrained context. Future endeavours are required to overcome these limitations.

Conclusion

This review provides an overview of empirical research that has adopted co-design approaches in developing interactive technologies for mediating family connectedness. A search of literature from the Scopus database was conducted, followed by a further identification of literature by snowballing from the reference lists. Seven studies were eventually included for final analysis.

According to our analysis, the included research employed mainly qualitative methods to closely work with families, with interviews as the most often adopted method across the pre-design, generative, and evaluative phases. Cultural probes and technology probes were used to provoke insights from families, aligning with Sanders and Stappers' (2014a) theoretical framework of co-design. A range of low- and high-tech tools were used to facilitate co-creation, and prototypes were generated to be deployed in the evaluative phase for collecting feedback from the participating families.

We identified four challenges of co-designing with families, related to scheduling conflicts, the diverse backgrounds of families, technical difficulties, and setting free the participants' imaginations and creativities in co-design activities, that make it difficult to partner with a sufficient number of families in design for a long duration. The design implications drawn from the review centre on seeking solutions to concerns about privacy, remote mediation, and diverse perceptions of playfulness and on the benefits of leveraging familiar objects and shared activities.

Although this review is limited by focusing only on English publications from primarily Western contexts, it provides a primary overview of co-design methodology considerations and insights into technology-mediated family connectedness. To gain a more global understanding in this research area, future reviews could be conducted by facilitating cross-cultural collaboration and expanding the scope of publications.

Data availability

Data for this study has been extracted from the *Scopus* database. There are 163 pieces of literature extracted from this database, remaining 7 pieces for analysis. All the reviewed articles can be found and accessed from the database. Extracted data is provided in the Excel file named 'Supplementary Information_Extracted Data'.

Received: 28 March 2024; Accepted: 30 October 2024;

Published online: 23 November 2024

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Acknowledgements

We would like to thank the Eric C. Yim Endowed Professorship in Inclusive Design (PolyU Ref.: 8.73.09.847K) and the Rpg studentship of The Hong Kong Polytechnic University. Our thanks are also given to the partial research support of the PolyUHIT Joint-Research Center for Inclusive Environment and the EdUHK Research Grant (Project code: R4407 and 04898).

Author contributions

All three authors have contributed to the whole process of literature identification, screening, and assessment. The first author is responsible for the review analysis, manuscript planning, writing and revisions; the second author is responsible for the writing and revisions of manuscript; and the third author is responsible for the management of the project and study, and the writing and final proof-reading of the manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

Additional information

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1057/s41599-024-04043-9>.

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