EchoArtLink uses digital art as a trigger to enhance the social connectedness between parents and children living apart

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Abstract

As families become increasingly dispersed due to global migration and the pursuit of opportunities, maintaining emotional connections between distant parents and children becomes a critical challenge. EchoArtLink addresses this by leveraging sound visualization to enhance social connectedness across long distances. This system offers two methods of sound visualization: visualizing activities recognized from sounds (Method activities) and visualizing the sound features directly without recognizing activities (Method features). A mixed-methods evaluation with 10 participants revealed no significant differences in connectedness when measured quantitatively; however, qualitative feedback highlighted the distinct advantages of each method in fostering social connectedness. Method (features) subtly enhanced intimacy through rich sound detail, while Method (activities) facilitated a clearer understanding of daily routines. These findings suggest that combining both methods could better sustain emotional connections in dispersed families. This research contributes to the field of social connectedness by offering a novel system and valuable insights into the role of sound visualization in long-distance family communication.

Keywords: Social Connectedness, Family, Digital Art

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1 Introduction

The World Health Organisation reports that[16]an unprecedented number of people are relocating from their homelands, with the current global migrant population estimated at 1 billion. It is not only the immigrant population but also those who seek better job and education opportunities who have to choose to live apart from their parents[15]. Geographical separation over long distances challenges the emotional connection between parents and their children[26]. This situation weakens the social connectedness between children and their parents.

As technology continues to develop, it is becoming increasingly integrated into our home lives[7]. Previous research has shown that technology can offer opportunities to strengthen parent-child bonds, enabling people to share their stories and feelings with their parents or children anytime, anywhere they are[7][21][24][15]. Today, technology extensively supports the use of social media platforms like WhatsApp, Facebook, and Instagram for messaging, audio and video calls, interactive communication, and more[20]. However, despite these advancements, social connectedness between parents and children living apart remains limited. Differences in living conditions, time zones, and work schedules often make it difficult for parents and children to find time to connect and understand each other's daily lives. This can hinder the ability to maintain constant communication and companionship. In recent years, the close integration of art and technology has led to the rise of digital artworks as a significant part of people's everyday experiences[11]. These digital creations are no longer just objects to be viewed; they also serve as tools for fostering connectedness between people by creating shared experiences. This fusion of art and technology offers a new, creative avenue for communication and expression, helping to bridge the gap in relationships, particularly between those separated by distance.

Therefore, we propose the use of digital art to enhance the social connectedness between parents and their children.EchoArtLink is a pioneering system that collects sound data and transforms it into digital art, which is then displayed in family photo frames. The system strengthens connectedness in two ways: first, by visualizing activities recognized from sound(Method(activities)); and second, by Visualizing the sound features directly without recognizing activities(Method(features)). Additionally, our qualitative study provides insights into the differences in how different methods of sound input influence a sense of connectedness. EchoArtLink introduces a new system to strengthen social connectedness between family members living apart, acting as a trigger to stimulate curiosity about each other's living

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situations, thus facilitating conversations and the sharing of daily life.

The main purpose of this study is to use digital art as a trigger to enhance social connectedness between parents and children living apart, and to explore the differences in the effects of two sound visualisation methods on influencing a sense of connectivity. Therefore, the following research question is posed: "How do two visualization methods affect social connectedness differently between parents and children living apart?"

2 RELATED WORK

2.1 Social connectedness

Social connectedness is divided into three tiers, with the most intimate tier being partner family members, the next closest being close friends and acquaintances, and then strangers with whom we interact[23]. Previous research has shown that a strong sense of positive social connectedness primarily emerges within the context of mutual care and understanding, specifically among the most intimate relationships such as family members and partners[2]. Retired older people who live alone are lonely in such relationships because they have little contact with other people have a lot of free time after retirement, and are not surrounded by their loved ones. So they are more likely to feel lonely[12][10].

This feeling of loneliness often stems from the lack of intimate attachment relationships.[23] Social connectedness is also related to the concept of social support, which is defined as the people closest to us—those we can depend on—who let us know they care, value, and love us. Thus, social connectedness between parents and children becomes particularly important on this basis[23] [18]. In many families, parents may have more than one child, and those who can feel loneliness are not limited to just the parents. This includes children with only one parent, who also greatly need emotional connection.

2.2 Emerging technologies to support social connections

Of the many systems working to improve home connectivity, most of them focus on showing the current state of life and health of family members[4]. For example, the Digital Family Portrait[17] and CareNet[5] systems both provide information to remote caregivers about the health status and living conditions of older adults. Some works have also provided systems for bi-directional emotional transmission. Robo-Shoe-Files[8] is a small device that has been given a special requirement to interact with other users wearing the same device. This interaction is facilitated through specific movements between the devices, such as shaking feet together. The device uses built-in sensors (such as infrared sensors) to detect the presence of other devices nearby and prompts the wearer to interact through light and sound feedback.

Some work has also designed prototypes that require active information sharing so that family members can learn about each other's lives and exchange information. Examples include digital sticky notes[13], scanned information and the dissemination of information between families displayed on a website[19]. eKiss[9] enables efficacy between children and parents through photo software, which is displayed on the family's monitor or on the parents' mobile phones.

Some prototypes have also explored dedicated connections between long-distance families to allow for better interaction among family members, such as the shared storytelling system proposed by René Vutborg[24], which provides a platform for grandparents and grandchildren living apart to interact with each other by integrating features such as story reading, photo sharing, interactive drawing and audio dialogue. The platform not only simulates the intimate activities that grandparents and grandchildren do when they spend time together, such as reading stories together, but also enhances their emotional connection and communication by sharing daily photos and interactive drawings. The Messaging Kettle[3] can detect kettle usage via a heat sensor while the user is making tea, sharing it with a similar device in another home, making the daily use of the boiling kettle visible off-site. Users can also exchange voice messages and doodles using the Smart Tea Box. The Fitbit Flex[14] wristband offers new opportunities for parents to monitor their children when they are separated by sharing their children's sleep and physical data across the family, which studies have found parents often use to ask their children for information about specific activities.

All of these works focus on social connectedness and can increase the social connectedness of family members. However, some designs require active sharing, while others compromise users' privacy, which over time can lead to resistance towards the system or device. Although it is challenging to completely avoid privacy and ethical concerns in life-sharing systems, the use of abstract digital art may help mitigate these issues. By rendering data in a less specific form, abstract art can spark curiosity while still conveying a sense of life's state, thus preserving privacy. In this study, we propose EchoArtLink, a system that visualizes sounds from daily life as abstract images. Our goal is to explore whether digital art interventions can effectively enhance the social connectedness between parents and their children living apart and to examine the differences between the two methods of sound input in fostering a sense of connectedness.

3 DESIGN RESEARCH PROCESS

3.1 User Research

To design our system, I invited 10 participants (5 parents and 5 young adults) for context studies through online interviews. These participants were in a state of separation from their children or parents. The context study had two objectives: one was to concretely understand the current status of emotional connections in long-distance families; the second was to understand what forms of expression they desired. I then discussed their maximum limit for privacy and whether the use of digital art might potentially support emotional connections within families.

According to the results of the interviews, it is learnt that especially children living apart from their parents who are busy with their studies and work communicate with them only once a week or even less frequently. Moreover, children are not very concerned about their parents' living status, they seldom take the initiative to ask their parents about their living status, on the contrary, parents are very curious about what their children are doing, but may hesitate to take the initiative to contact their children because of the worry that their children are busy, and their connection will become very weak over time. The key is that users are more resistant to wearing a wearable device to share, and do not want to show their status to each other. 5 children all said they preferred not to have to actively input their status to their parents, as they may not have the time to do so and it would be tiresome to do so for a long period.

These user feedback and related work summaries reveal our system's key design implications. The following section describes the design concepts in more detail.

3.2 Initial design concept

In the first phase of the design process (Figure 1), I experimented with using an app as a tool for connecting family members. However, during the user study, we found that people did not like having to open their phones again and the need for active input. Therefore, I went back to the user research phase to gather essential insights and concluded that users desire a way to share their lives that doesn't require time investment and is interesting, yet doesn't overtly display specifics of their lives. Consequently, my focus shifted to passive input and data that could represent one's state of life. In searching for such data, I discovered that sound could represent any state of life and personal activity. Thus, in my second design concept (Figure 2), I chose to use sound data to visualize personal activities, with screens in both the user's and their parent's homes to view the activity visualizations, fostering an understanding of each other's life states. To test the feasibility, I developed a prototype using Processing to collect sounds, which underwent a simple test. I found six participants, two parents, and four children for the user

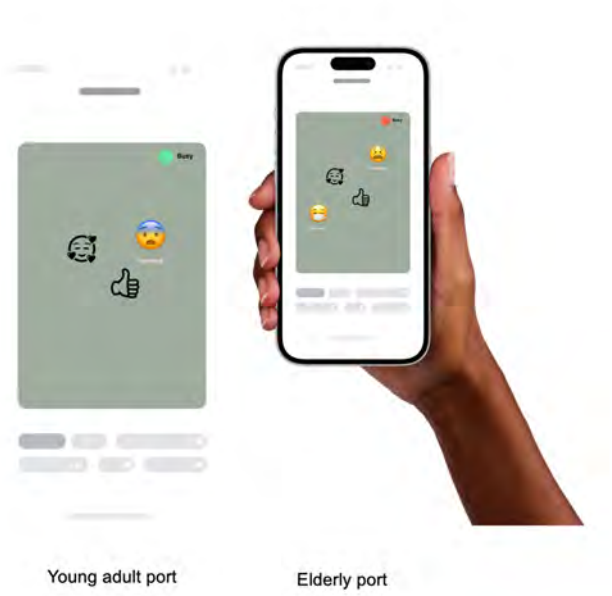

Figure 1. First design concept

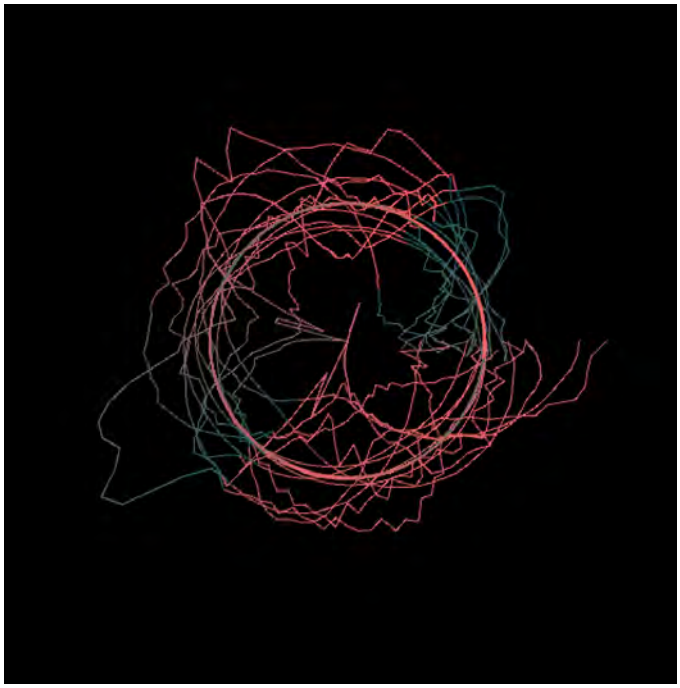

Figure 2. Second design concept

test. The feedback was positive, with all participants feeling that it sparked curiosity and encouraged them to reach out to their parents. However, most participants mentioned they were unclear about what activities the patterns represented. They also mentioned that the shapes and colours of the visualization could represent states of life. Specifically,

one participant noted that while they were initially curious because they didn't know what their parents were doing, they felt the approach lacked interactivity, and they couldn't discern what activities the patterns corresponded to, leading to a gradual loss of interest in the prototype.

4 FINAL DESIGN IMPLEMENTATION

4.1 Sound Visualisation

Based on insights gathered from participant feedback and literature review, the method of visualizing life states through collected sounds was found to be an effective tool for enhancing communication between parents and children living apart. Building on the suggestions from participants and the recommendations from the coach, I refined and optimized the design concept accordingly.

4.2 Two methods of implementation

This study used two methods of collecting sound for visualisation to enhance social connectedness between parents and children and to find out how the two methods differed in creating a sense of connectedness.

4.2.1 Visualizing the sound features directly without recognizing activities. During the design and implementation of this project, I developed a programme that transforms real-time captured sound signals into dynamic visual artworks through signal processing. By deeply analyzing the key features of the sound stream (frequency, duration, and volume), the application can generate a series of dynamic and varied linear patterns that visually capture and express the essence of sound. These linear patterns dynamically dance across the screen as the incoming sounds change, creating an ever-evolving digital art image.

This system collects all sounds, including human voices, ambient sounds as well as human-made noises, and the features of these sounds are visualised. Since it collects sounds and visualises the sound in real time the whole visualisation process is also real time and the user can observe how the sound changes affect the visualisation.

4.2.2 Visualizing activities recognized from sound. Another implementation is to recognise and visualise specific sounds of activity through machine learning techniques. The project began with the collection of a series of sound samples representing different sound activities (such as the sound of water flow, keyboard typing, and knocking on doors). These samples not only covered a variety of common sounds but were also carefully labelled for subsequent processing.

Using Python as the development language, we first conducted feature extraction on these audio files using the Librosa library, accurately extracting the Mel Frequency Cepstral Coefficients (MFCC) for each sample. MFCC is a widely used feature representation in the field of sound recognition.

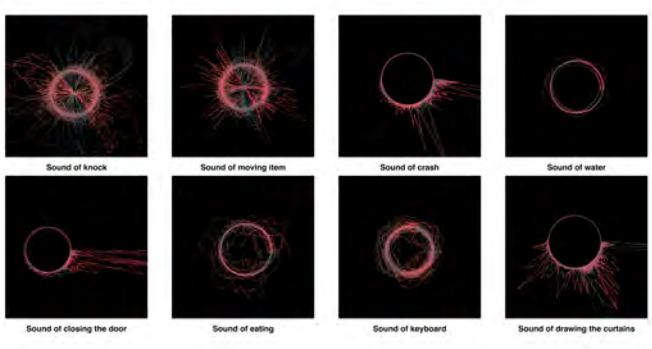

Figure 3. Images corresponding to each of the activity sounds.

These features were then used to train a Support Vector Machine (SVM) model, a powerful machine learning algorithm that efficiently handles classification problems. We chose a linear kernel and optimized the model performance by adjusting the regularization parameter C, aiming to achieve the best differentiation effect between different sound activities.

During the model training and validation process, we employed cross-validation methods to evaluate the model's accuracy. By dividing different sound data into multiple types and alternately using one of these sound types as the test set, the model undergoes multiple rounds of training and testing to ensure the accuracy of machine learning in recognizing sounds and generating images. Lastly, we achieved a high-accuracy sound recognition system by continuously adjusting parameters and optimising algorithms. Additionally, we built a user-friendly graphical interface using the Tkinter library. We pre-stored visualization images generated by signal processing in the database, with each sound corresponding to a specific image (Figure 3). This allows for the real-time display of sound recognition results and dynamically generates specific digital art images based on the recognised sound activity.

4.2.3 Contexts and scenarios of use. The visualisations generated by the two methods are displayed in picture frames in the home (Figure 4), both the children and the parents have two picture frames in their home, one to show the other's activities and one to show their own, this is so that the other can understand the meaning of the visualisation, for example the child's picture frame appears to have the same pattern as their own picture frame this suggests that perhaps the child is doing the same thing as they are, or perhaps they aren't, this can be wrong, but the user can learn the meaning of the visualisation process. Here the two methods are independent and are not used together but separately.

Sound is collected by attaching a microphone to the picture frame, which avoids the privacy concerns of using a mobile phone to collect sound and does not allow too much sound data to interfere with the generation of visualisations.

Figure 4. Visualisation applied to real scenarios.

The picture frames will be installed in places that are part of the normal life routine such as the living room or bedroom. When parents and children see each other's picture frames at the same time and start to visualize, it may arouse curiosity and remind them of each other's existence, which will lead to interaction, making sounds or further communication in other ways. This is also one of the reasons not to use mobile phones to collect sounds. If sounds were input daily, the images in the picture frames would change constantly, making the experience feel ordinary for users. They wouldn't perceive it as a special action from the other side, lacking a sense of surprise and wonder. It would just seem like a routine occurrence, and over time, this system would fail to pique the other's curiosity.

5 METHOD

This paper compares the two sound visualization methods to understand their impact on social connectedness between parents and their children living apart. We present a within-subjects repeated measures experimental design(i.e., all participants test all conditions), with the visualization method as the independent variable with two levels: 1) Visualizing activities recognized from sound, and 2) Visualizing sound features directly without recognizing activities. To ensure the external validity of the evaluation, participants performed eight different tasks in each condition, each of which was equal to a real-life usage scenario. After completing the task, they were required to make a voice call to their parent, and then the experimenter would put the participant's phone in another room to visualise the parent's sound. This study used semi-structured interviews, and questionnaires to collect data and mixed methods[22] were used to validate all findings. We first discuss the participants, and study apparatus, after which we outline the detailed study procedure and data analysis method.

5.1 Participant

A total of 10 participants separated from their parents were recruited for this experiment (3 females and 7 males, age M=23.9). All participants were separated from their parents for at least three months and they were between the ages of 18-35 and unmarried.

5.2 Apparatus

To simulate a more realistic living environment, the experiment was conducted in the participants' homes(Figure 5). There will be a picture frame with an embedded tablet to display the visualisation images for participants to set up where they find it easy to see and a laptop to collect the sounds for visualisation. In the interviews, a phone was used as the recording device, and each participant was given two questionnaires and a consent form.

5.3 Procedure

The experiment was conducted in the living rooms of the participants' homes. The experiment proceeded through a series of consecutive steps: introduction, Method(activities), Method(features), and a concluding interview. The total duration for each participant was approximately 113 minutes(Figure 4).

5.3.1 Introduction. Before the start of the experiment, participants were given a brief introduction to the purpose and procedures of the experiment and were provided with a consent form. After signing the consent form, participants were required to complete the IOS scale based on their current emotional connection with their parents.

5.3.2 Experiential Methods. The main part of the experiment involved experiencing two visualization methods(Figure 4). During the second and third phases, participants were required to complete eight tasks (Table 1)to produce sound (including closing doors, water sounds, knocking sounds, keyboard typing, crash sounds, eating, moving items, and drawing the curtains.) to generate visualization images on the screen. After completing these tasks, participants contacted their parents via a phone call and informed them about

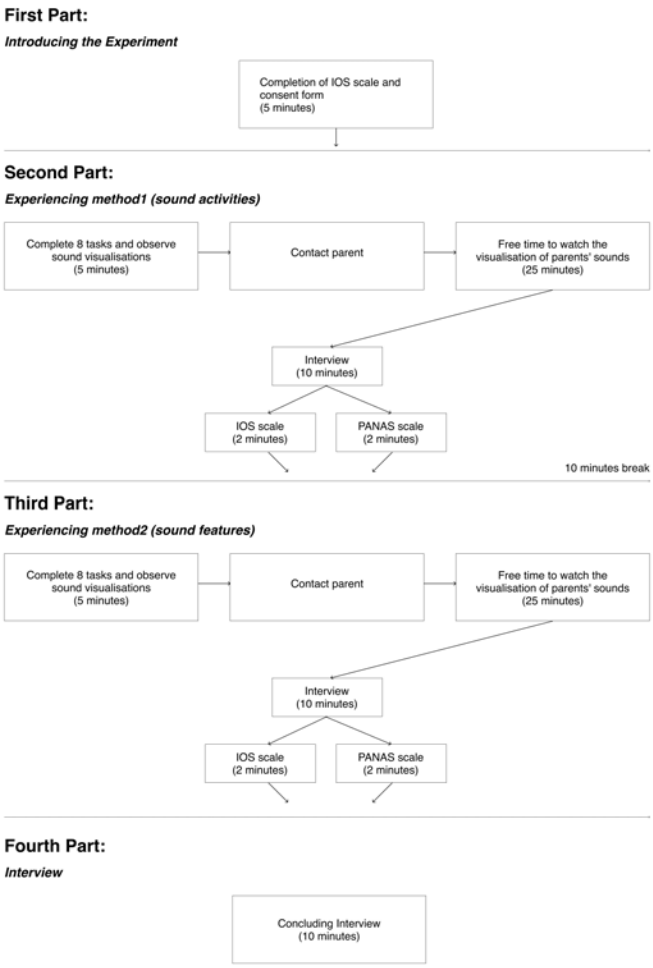

Figure 5. Experimental procedure

Figure 6. Examples of participant testing environments

Table 1. Tasks to be completed by participants.

Task	Description
Crash sound	Object collision sounds
Knocking sound	Knocking on tables and doors
Water sound	Turning on a tap
Curtain drawing sound	Sliding the curtains
Eating sound	Eating fruit
Item moving sound	Moving a chair
Door closing sound	Closing the living room door
Keyboard sound	Typing on a keyboard

In the experiment both methods have the same tasks.

Figure 7. Collecting and visualising participant's parents' sounds in another room

the experiment's requirements. The experimenter then took the participants' phones to another room to visualize the everyday sounds of the participants' parents on the screen for the participants to observe (Figure 6). During this period, participants and their parents could neither communicate nor hear each other, and the participants could only view the sound visualizations of their parents through the picture frames. To simulate normal life, participants were free to move around their homes and continue their activities without any restrictions, as they normally would. After 25 minutes, a ten-minute interview was conducted to inquire about the participants' feelings and how the method affected their emotional connection. Subsequently, participants were asked to complete the IOS and PANAS scales.

It is important to note that, to ensure fairness and avoid bias, the order of Method(activities) and Method(features)

was alternated after each participant completed the experiment.

5.3.3 Concluding Interview. After participants have experienced both methods and completed the interviews and questionnaires, there will be a concluding interview. This interview will inquire about the participants' feelings regarding how each method affected their emotional connection with their parents and the differences between the two methods. This is an open-ended interview, allowing participants to discuss the strengths and weaknesses of each method and their individual preferences.

5.4 Measures

This study evaluated the effects of two distinct visualization methods within the EchoArtLink system on the perceived connectedness between parents and their children. This was assessed using the Inclusion of Others in the Self (IOS) Scale (Appendix C) [1] and the Positive and Negative Affect Schedule (PANAS) (Appendix C) [25]. The PANAS was administered once after participants experienced each visualization method to measure their current emotional states influenced by the EchoArtLink system, providing insight into their feelings and overall perception of the experience. In contrast, the IOS scale was administered three times: initially to determine baseline closeness between the participant and their parents, again after engaging with the first method (activities), and finally after experiencing the second method (features). The experiment included a total of three interviews, all of which were audio-recorded for analysis.

5.5 Data Analysis

Our data include audio recordings of semi-structured interviews, the IOS scales, PANAS scales and observation notes.

Quantitative data obtained from the scale were organized and analyzed in Microsoft Excel. Subsequently, ANOVA post-hoc tests were used to calculate the means, standard deviations, and p-values.

To qualitatively analyse the participants' behavioural data, notes were reviewed to identify the circumstances under which participants would view the picture frames, as well as analyse any patterns of facial expressions or repetitive behaviours, focusing on noteworthy instances and any contextual factors that might explain the participants' behaviour.

To analyze participants's interview responses, we transcribed the audio recordings of the interviews using otter.ai, then manually cleaned and corrected the transcripts. This study used an inductive and thematic coding approach[6] to analyze participants' responses. By reviewing all interview transcripts, highlighting key sentences, and categorizing related responses into themes, we aimed to thoroughly understand participants' experiences in real-life contexts and capture their perspectives. This method was complemented by behavioural data analysis to provide a comprehensive view of the participants' authentic experiences and insights.

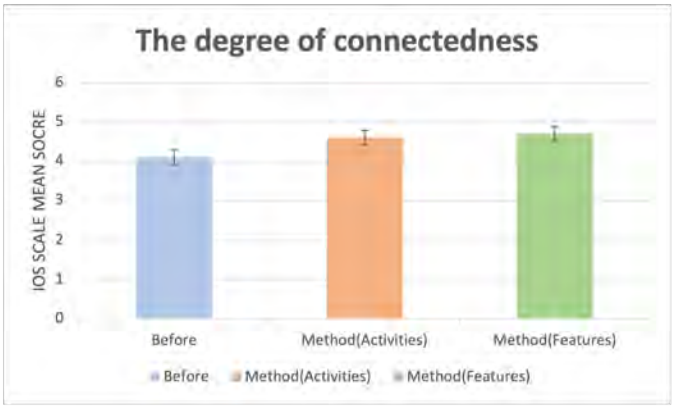

Figure 8. Mean differences and standard errors in the connectedness factor, measured by the IOS scale

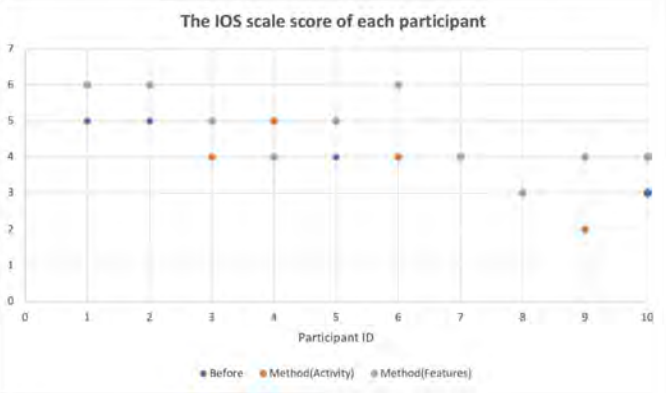

Figure 9. The IOS scale score of each participant

6 RESULT

6.1 Children and Parent Connectedness

Overall, sound visualisation can give a sense of increased closeness to young adults who are living apart from their parents. Below are the mean scores and standard deviations by calculated for each factor in the IOS scale.

Before young people experienced the EchoArtLink system, the initial IOS scale had a mean value of M=4.1 (SD=0.70). After experiencing the two methods, the between-subject effect on social connectedness showed the following results: Method(activities) had a mean value of M=4.6 (SD=1.06), and Method(features) had a mean value of M=4.7 (SD=1.16). Furthermore, no significant differences were found between the Method(activities) and Method(features) conditions ($p=0.513 > 0.05$).

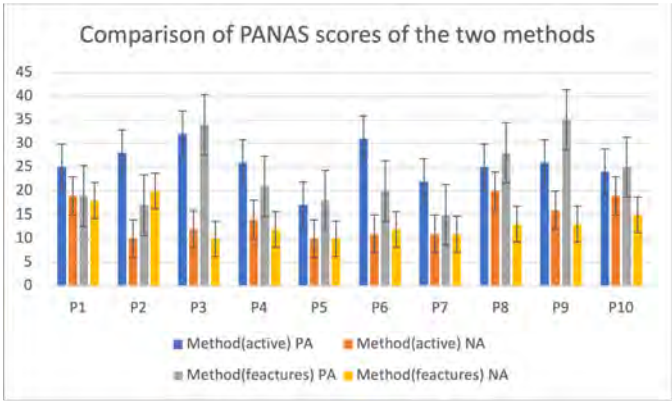

Figure 10. The PANAS scale score of each participant

6.2 PANAS analysis for each participant

Meanwhile, data indicates that out of 10 participants, 6 felt closer to their separated parents after experiencing the two sound visualization methods(Figure 8). The remaining 4 participants(P3, P7, P8, P9) showed no significant difference in their IOS scale scores before and after the experience, indicating that sound visualization did not enhance their sense of social connectedness. Worth noting, that two participants(P3, P9) experienced a decline in their scores after trying the Method(activities), indicating that their sense of social connectedness decreased.

The mean values and standard errors of the perceived effectiveness of each method as measured by the Positive and Negative Affect Schedule (PANAS) are shown in Figure 9.

A one-way ANOVA was conducted to compare the effect of the two methods on PA and NA scores. The Method(activity) had a mean PA score of M=25.6 (SD=4.83) and a mean NA score of M=14.2 (SD=3.99). The Method(features) had a mean PA score of M=23.2 (SD=6.35) and a mean NA score of M=13.4 (SD=3.73). There was no significant effect of the method on PA scores at the $p < 0.05$ level for the two conditions [$F(1, 18) = 0.8443$, $p = 0.37032$]. Similarly, there was no significant effect of the method on NA scores at the $p < 0.05$ level for the two conditions [$F(1, 18) = 1.357542$, $p = 0.259173$]. These results suggest that the type of Method (activity or features) does not significantly influence either PA or NA scores.

6.3 Quantitative Analysis Summary

The quantitative analysis was conducted to evaluate the perceived intimacy and effectiveness of two different methods using the IOS scale and the Positive and Negative Affect Schedule (PANAS). The IOS scale results indicated that there was no significant difference in perceived intimacy between Method(activity) and Method(features), with mean scores of M=4.6 (SD=1.06) and M=4.7 (SD=1.16), respectively. A one-way ANOVA confirmed that the type of method did not significantly influence the perceived intimacy [$F(1, 18) = 0.680843$, $p = 0.513158>0.05$].

Similarly, the PANAS results showed no significant differences in the perception of each method. Method(activity) had a mean PA score of M=25.6 (SD=4.83) and a mean NA score of M=14.2 (SD=3.99), while Method(features) had a mean PA score of M=23.2 (SD=6.35) and a mean NA score of M=13.4 (SD=3.73). One-way ANOVA results for PA scores [$F(1, 18) = 0.8443$, $p = 0.37032>0.05$] and NA scores [$F(1, 18) = 1.357542$, $p = 0.259173>0.05$] both indicated no significant effect of two methods.

In summary, these results indicate that the type of Method (activity or features) does not have a significant impact on perceived intimacy or perceived effectiveness as measured by the PANAS and IOS scales.

6.4 Interview for Method(activities)

6.4.1 Curiosity driven. All participants in the experiment expressed curiosity about what their parents were doing. This curiosity drove them to actively inquire about the situation when they saw the image either change dramatically or remain unchanged for a long time. For instance, Participant 2 mentioned, "If I keep seeing the same image without any movement, I might get curious and wonder what's going on there. Aren't they supposed to be eating? Why isn't there any reaction? I might call to ask." This curiosity not only increased their attention to their parents' activities but also promoted interaction and communication among family members. Participant 1 added, "This visualization has sparked my curiosity about their lives. They might not be curious themselves, but I have become curious." Participant 3 noted, "I remember my mom usually makes a lot of noise, but today the image didn't change much. It made me feel like I don't know her as well, so I want to ask her about it." These unusual image changes prompted participants to pay attention to and discuss anomalies in daily life.

Although most people showed strong curiosity, five participants found it difficult to understand specific activities due to the short experience time. Participant 7 said, "If I see an image I'm not familiar with, I'll be curious about what my parents are doing, but it's hard to connect it to specific activities because I'm not familiar with the image." This situation indicates that participants need more time to adapt to and understand the connection between these images and actual activities.

6.4.2 Sense of companionship. Four participants mentioned that this visualization method enhanced their sense of companionship, making them feel as if their parents were right beside them. Participant 2 said, "I often talk to my mom on the phone without saying much, but I can infer what she's doing from the sounds. This method gives me a similar feeling." This indirect way of communication, through changes in sound and images, allows participants to sense

the presence of their family and the rhythm of daily life. Participant 1 remarked, "Being able to make guesses based on my understanding combined with the images if I know they're also having dinner, it makes the sense of companionship stronger." This experience of synchronous activities makes participants feel closer and more connected. Participant 4 said, "This method conjures up images of being at home, as if we are all there, each doing our own thing. The Sound Visualisation aren't particularly clear or informative, but there's a sense of life."

6.4.3 Privacy and ambiguity. Three participants felt more like observers, gathering information by watching their parents' activities. Participant 8 said, "I feel more like an observer, watching my parents' activities. Even though the images are blurry, they still provide information and protect privacy well. Sometimes I want to maintain a certain distance from my parents, and this could become a topic of conversation, prompting me to ask what's really going on." Participant 2 said, "This gives me a sense of mystery. My parents' activities are still quite vague, but I'm not particularly interested in knowing exactly what they are doing. I just want to feel their presence.

6.4.4 Sense of connection. Most participants felt they couldn't fully identify the images in a short time, but three participants said they didn't particularly care about what the others were doing, as long as they could roughly understand that the other person was active. Participant 2 mentioned, "The images were like a cue for me to understand what they were doing." This indirect hinting and guidance allow participants to maintain a certain level of connection and awareness in their daily lives without needing real-time and detailed information. This vague sense of connection allows participants to feel the presence and support of their families even amid their busy lives. Participant 6 said, "Maybe when I'm not doing anything, I glance at it, and I might roughly guess what they are doing. It brings a feeling of closeness, but it's hard to connect it to specific activities because I don't know what most activities represent."

6.5 Interview for Method(features)

6.5.1 Richness of Information. Many participants mentioned that although this method can convey many sound details, the amount of information can sometimes be overwhelming, making it difficult to analyze what the other person is actually doing. Participant 2 stated, "This method conveys more information and subtle details, but sometimes the amount of information can be too much, making me feel confused." Participant 7 said, "This form of expression is not limited to the sounds of my parents; it includes other sounds as well, making me think not only of my parents but of everything at home, like pets, for example." Participant 6 commented, "If the image is changing, it indicates some activity, even subtle sounds. I would think about whether my mom is doing housework or something else, like if the mop fell over. This gives me a different kind of feeling."

6.5.2 Vague directionality. Most participants felt that the method's directionality was not very intuitive and did not provide clear indications of activities, requiring more guessing and imagination. Participant 2 remarked, "This state lets me feel things more intuitively, like if it's quiet, I can immediately know there's no sound at all, but there are no clear prompts. I need more guessing and imagination, but I can't picture it in my mind." Participant 4 stated, "I can't quite tell what my mom is doing because I'm not very familiar with her schedule. If I knew roughly what she was doing, I could imagine it, but since I don't know much, it doesn't feel very clear to me." This vague directionality makes participants rely more on guessing and imagination to understand the information conveyed by the images. This lack of clear direction often leaves participants uncertain about the exact activities their parents are engaged in, making the experience feel less precise and more reliant on their own assumptions and interpretations.

6.5.3 Sense of distance. Four participants mentioned that this method brought them closer to their parents because it felt like their parents were talking to them, though not very explicitly. Participant 3 said, "This visualization with sound features makes me feel like my parents are far away yet right in front of me. Even without sound, I can imagine what it's like to talk to them. Looking at this image, I have a sense of missing them—so close yet so far." Participant 9 suggested, "I think this method is suitable for relatives who are not very close. You don't want them to know exactly what you are doing, just that you are active. If it were me, I would use it for my grandparents."

6.6 Summative analysis on two methods

6.6.1 Curiosity and sense of connection. Both methods elicited curiosity and a sense of connection among most participants, allowing them to feel more engaged with what was happening in their parents' lives. However, there were some subtle differences between the two methods.

6.6.2 Details of sound. Six participants mentioned that Method (features) conveyed more subtle sound details, while Method (activities) only informed participants about the activities their parents were doing. Participants with closer relationships with their parents preferred receiving more sound details, which made them feel a greater sense of closeness. Participant 7 noted, "I think it's not just my parents' sounds; it could also be my pets' sounds." These subtle differences are something that Method(activities) cannot achieve.

6.6.3 Imagination and Space. On the other hand, some participants felt that Method(activities) allowed them more space for imagination. Even though the details might be vague, they could guess what their parents were doing at

home based on the images. Looking at the images, it felt as if their parents were right in front of them. In contrast, if they only received sound features, they could not visualize their parents at home in their minds.

Participant 4 stated, "Visualizing activities recognized from sound allows me to imagine what my parents are doing at home. Looking at these images, I feel like they are right in front of me. If it's just sound features, I can't construct an image of them at home in my mind."

6.6.4 Influence of Parent-Child Closeness on Method Preferences and Interaction Depth. Based on both qualitative and quantitative analyses, we found that participants with lower levels of closeness to their parents tended to prefer the Method (features). These participants desired to maintain a certain degree of emotional distance while still seeking a subtle sense of parental presence. In contrast, participants with higher levels of closeness to their parents expressed a liking for both methods but showed a stronger preference for Method (activities). They were particularly interested in obtaining more detailed and specific information, which facilitated deeper interaction and communication with their parents.

7 DISCUSSION

In this paper, we present the design and implementation of two sound visualization methods. We conducted relevant experiments to compare the impact of these methods on the social connectedness between parents and children in long-distance families. To achieve this goal, the study tested both Methods (activities) and Methods (features). The value of this research lies in measuring the perceived social connectedness through the two methods and identifying key differences to further enhance user experience, making it more perceptible to users. The study demonstrates the potential of digital art and sound visualization in strengthening social connectedness in long-distance families and provides an in-depth understanding of different sound visualization methods, laying a foundation for future related research.

The results of this study are generally consistent with previous research on technology-enhanced parent-child relationships. Earlier studies have shown that technology can strengthen these relationships by providing opportunities to share stories and feelings[17][24][15]. Our research further expands this field by exploring new methods using digital art and sound visualization, offering new ideas for enhancing social connectedness within families. The results of the study are discussed in further detail below.

7.1 Sense of social connectedness

The IOS scale measurements revealed no statistically significant difference between the two methods regarding their impact on perceived intimacy. Similarly, the PANAS scale results showed no significant variance in participants' emotional responses to each method. These quantitative findings suggest that both Method (activities) and Method (features) are equally effective in fostering a sense of social connectedness from a statistical standpoint. However, the qualitative analysis provided deeper insights into how participants interacted with and perceived each method.

Participants with lower levels of closeness to their parents tended to prefer Method (features). This method conveyed rich sound details, which allowed these participants to maintain a degree of emotional distance while still experiencing a subtle sense of their parent's presence. The richness of auditory information, though less explicit in terms of specific activities, enabled participants to feel connected without the need for direct or detailed engagement. This was particularly appealing to those who valued a more reserved and less intrusive form of connection, where they could appreciate their parents' presence without delving into specific details.

In contrast, participants with higher levels of closeness to their parents favoured Method (activities). This method, with its clear activity directionality, provided specific visual cues that allowed participants to engage more deeply with their parents' daily routines. While it lacked the richness in detail that Method (features) offered, it excelled in intuitively displaying the activities of the parents, which was highly valued by those who sought a more intimate and specific connection. The explicit nature of this method enabled a more direct interaction, satisfying the participants' desire for a detailed understanding of their parents' lives, thereby facilitating deeper communication.

In summary, both methods offered distinct advantages in enhancing the connection between participants and their parents, with preferences closely tied to the participants' existing relationships. Method (features) excelled in providing a subtle, emotionally nuanced connection through rich sound details, ideal for those who preferred a gentle and less intrusive presence. Conversely, Method (activities) offered clear and specific visualizations of parental activities, appealing to those with closer bonds who desired a more detailed and engaging interaction. This suggests that the effectiveness of each method depends on the specific emotional needs and dynamics of the users, making each method suitable for different relational contexts.

7.2 Limitation and future work

The study's small sample size, with only 10 participants, limits the generalizability of the findings. The short duration of the experiment and the pre-existing communication habits between participants and their parents may also have influenced the results. Future studies should address these limitations by incorporating a larger, more diverse sample and extending the duration of the experiment to observe long-term effects. Installing the equipment in participants'

homes for an extended period, such as a week, could provide more accurate and realistic data on the impact of these visualization methods on social connectedness.

Additionally, improving the visual and auditory clarity of the methods to make the representations more intuitive and relatable to the parents' activities will be crucial in future iterations. Enhancing these features could help bridge the gap between abstract visualization and meaningful emotional connection, making the experience more accessible and engaging for users. Further research should also explore the integration of these methods into everyday technology, such as home devices, to increase their practical applicability and impact on maintaining emotional ties in long-distance relationships.

Through continued research and refinement, these sound visualization methods hold the potential to significantly enhance social connectedness and emotional communication between family members who are geographically separated. By understanding the specific needs and preferences of users, future developments can create more personalized and effective tools for sustaining familial bonds in the digital age.

8 CONCLUSION

This study explores the innovative use of sound visualization as a communication medium to enhance social connectedness between geographically separated parents and children. Through a comprehensive process of design, experimentation, and analysis, we sought to answer the critical research question: "How do two visualization methods differently affect social connectedness between parents and their children living apart?"

Our findings indicate that, while there is no statistically significant difference between the two methods in quantitative measures of social connectedness, qualitative insights reveal distinct advantages in each approach. Method (features) enriches the emotional connection by offering detailed sound cues that subtly enhance intimacy, allowing users to feel the nuanced presence of their family members. On the other hand, Method (activities) excels in providing clear and direct representations of daily routines, which simplifies understanding and strengthens the sense of shared experiences.

These insights highlight that the effectiveness of sound visualization methods may be contingent on the level of closeness between the children and parents, as well as their individual communication preferences. The results suggest that a hybrid approach, combining the detailed sound cues of Method (features) with the clear activity representations of Method (activities), could further enhance the user experience, catering to a broader range of emotional and relational needs.

The broader implications of this study suggest that sound visualization has significant potential as a tool for fostering social connectedness in an increasingly digital and geographically dispersed world. As technology continues to integrate more deeply into our daily lives, such innovative communication methods can play a crucial role in maintaining and enhancing emotional bonds between distant family members.

In conclusion, this research contributes to the growing field of digital communication by demonstrating the value of sound visualization in strengthening familial bonds across distances. The study provides a foundation for future exploration and optimization of sound visualization systems, paving the way for more personalized, effective, and emotionally resonant communication tools.

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