# A taxonomy of research addressing both psychological and physical well-being technologies.

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***Abstract*—Due to the rapid growth of automation and robotics over the last few decades, research on tangible user interfaces (TUI) for human well-being has gained considerable attention. Globally, there is an increase in physical and mental health issues, putting a strain on national health systems around the world. TUIs can help mitigate the negative impact of physical disorders, i.e. any physical condition that has an adverse effect on one or more important aspects of daily life. Mental illnesses are strongly linked to stigma, and structural barriers, including financial hardship, and a lack of services and resources. TUIs can improve the accessibility of treatment for such mental disorders by offering an alternative to traditional therapy. With the aim of identifying and explaining actual interfaces between mental and physical health facilities, this review focuses on a number of notable studies done on TUIs being used for human well-being, more precisely, for physical well-being, in therapeutic environments, as an assistive device, and for educational purposes. It also highlights their findings, working hypotheses, and potential research directions—as well as the obstacles and facilitators to their implementation.**

***Keywords:* Human-Computer Interaction, Tangible Interface, Well-Being, Socially Assistive Robot(SAR)**

## I. Introduction

According to the association between mental and physical health, poor mental health is a risk factor for chronic physical diseases(CPD), and people with serious mental health disorders are more likely to develop CPD. Similarly, a mental disease is more common in people who have continuous physical problems [16]. Thus, in order to live a healthy life, we must give our mental and physical health the highest priority. Additionally, the way we perceive education and learning is changing as a result of the use of digital technology including computers, mobile devices, video games, and social networking sites [17]. In order to choose what they prefer to learn, when they want to study it, and how they wish to learn it, people all over the world are moving their education out of the classroom and into their homes, libraries, Internet cafes, and work places with the help of technology. That's why, many researchers nowadays advocate tangible user interfaces for educational purposes to make learning more practical, enjoyable, and engaging [18]. For example, TUI frameworks are being used to teach and study artificial intelligence (AI) in higher education institutions, as well as to teach and learn other challenging subjects like geometry and chemical bonds. While basic skill levels, financial limitations, and other factors vary greatly among people all over the world, our traditional educational system doesn't give any noticeable consideration about it. Thus, if we can guide TUIs in the proper path, it could be the way of the future of education. Furthermore, the effects of loneliness and sadness on people of all ages around the world are also alarming problems. The elderly are becoming more isolated as a result of modern civilization, and this is especially the case when their children are relocated for further education or employment. Consequently, they are developing depression due to a lack of connections and communication with those closest to them, and their loved ones. This leads to some situations when therapy or a friendly company is required for them, however, due to the high expenses and other barriers, not everyone can undergo therapy. Thereby, TUIs are being employed and investigated in increasingly sophisticated ways for usage as assistance devices [19], [20], [21] which can act similar to their friends, as well as devices that promote healthy-living. Likewise, these assistive devices have proven to be quite beneficial in recent research for children who are disabled or have special needs [22], [23], [24], [25], [26]. Globally, there are numerous children who struggle with socializing, intellectual difficulties, and physical limitations. Different therapies may be helpful for them in order to make their lives simpler and easier and to

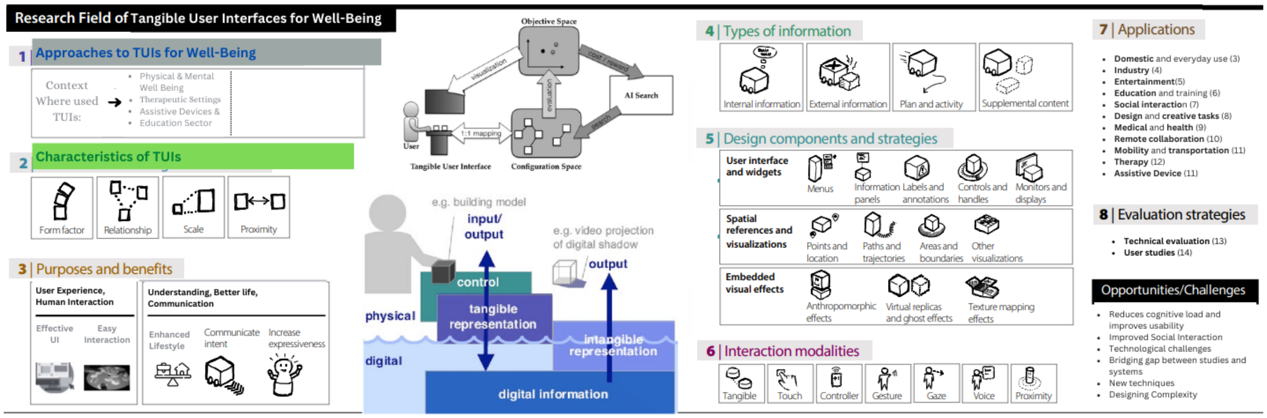

Fig. 1: Visual abstract of our survey and taxonomy of Tangible User Interface(TUI) for well-being, and summarizing eight key dimensions of the design space [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [11], [13], [14] [15].

minimize their challenges. Consequently, for children with learning disorders, tangible user interfaces currently occupy a vast and diverse research area. The elderly with dementia or other disabilities may also require therapy in order to live better lives. Researchers are investigating this issue and creating TUIs for therapeutic environments to engage with these people and give therapy in a pleasant way [27], [28], [29], [30], [31], [32].

Finally, this study offers a literature assessment and taxonomy that explores the use of creative interfaces for well-being in order to evaluate the potential of new technologies and how they may be applied to the education, therapy, assistive device sectors, and TUIs that promote both physical, and mental well-being. Adding with that, this survey aims to find how they are Transforming from the software/graphical elements to tangible objects showed in figure: 4 as well. The demand for all of these is rising, and cutting-edge solutions increasingly make use of robotic and other physical things, like socially assistive robots (SAR), mobile applications, sensing devices, tools for influencing behavior, and real-time intervention devices. In the health sector, where they are being used as tools for surgery, drug delivery, and diagnosis, robots are indeed becoming more prevalent [33]. Numerous studies have shown the positive impacts of social robot intervention on dementia patients' quality of life and well-being [34]. Similar to how tangible coaches are beneficial for the physical and mental well-being of elderly people [20], virtual coaches are also proven to be so through applications. In addition, tangible devices like the use of smartwatches and wearable technology in general, aside from the ubiquitous mobile phones, sensing devices, physical movement modifying devices, and behavior manipulation devices have already shown to be helpful for the well-being field [20], [35], [36].

Having a thorough overview on TUI research aimed towards physical and mental well-being could be beneficial, however, such a review is not currently available. In order to completely comprehend what kinds of tangible user interfaces have been constructed so far and to get in depth information about them, we did a literature review of the studies of tangible user interfaces.

With a quick visual presentation in figure: 1, we summarized the research area into the following design space dimensions: 1) methods for implementing TUIs for well-being; 2) TUI characteristics; 3) uses and advantages of using TUI; 4) classification of information presented; 5) design elements and strategies for TUI; 6) interaction methods and modalities; 7) application domains; and 8) evaluation methods. Our objective is to give researchers in the field, which encompasses TUI technologies for well-being reasons, an uniform language and framework. We hope that this study will be useful to researchers as they investigate new interfaces for human well-being and locate their work within the broad design space.

## II. Methodology and Discussion

In the recent past, the development of tangible interfaces for well-being objectives aquired a massive deployment, engaging users from all user groups, including children, the elderly, people with physical disabilities, and those with a very wide range of technical skills. There are many different sorts of interfaces that have

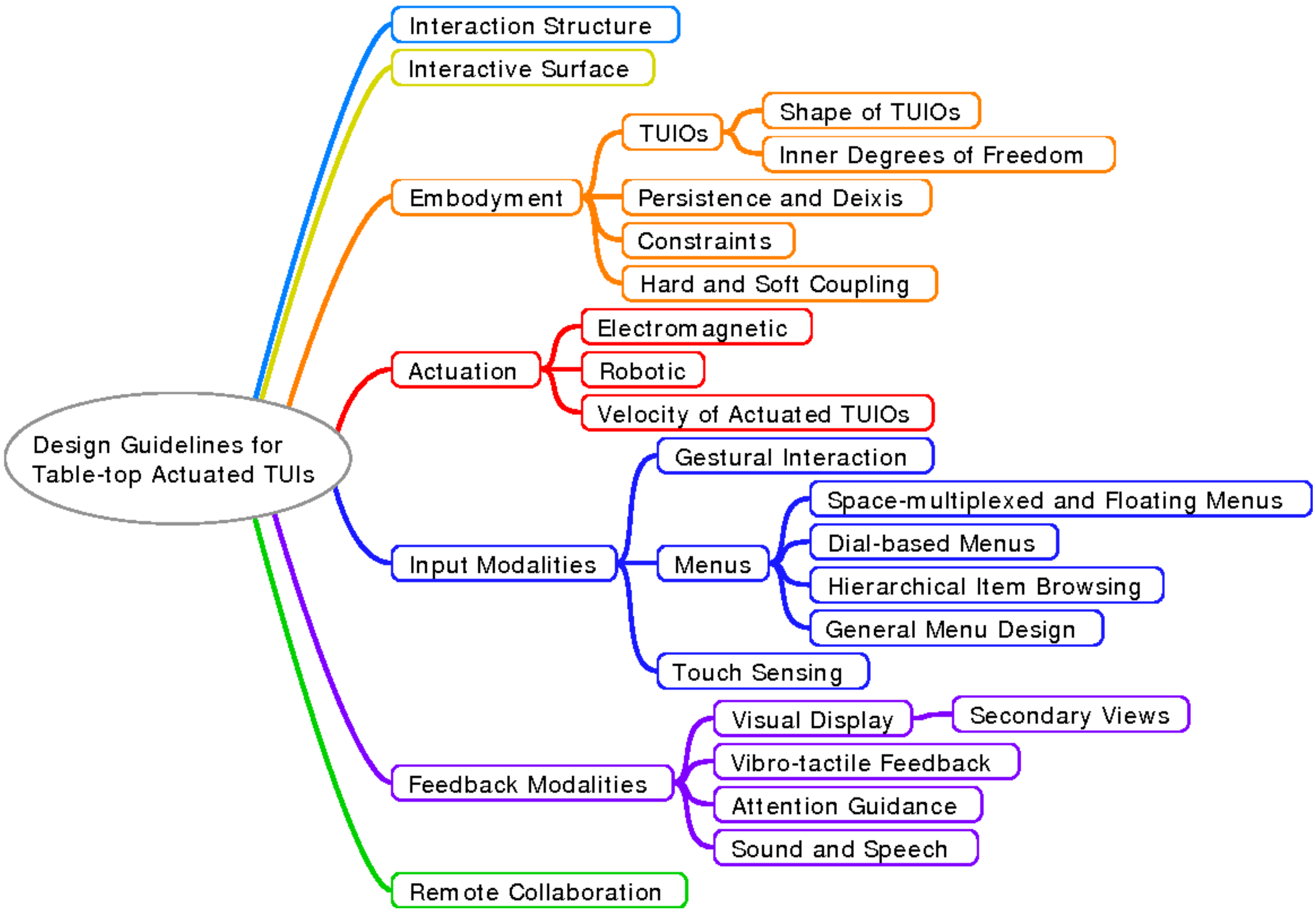

Fig. 2: Overview of the design guidelines of TUIs [37].

been developed depending on the user and application. In figure: 2, there is an overview of the design guidelines of TUIs divided into major seven subsections.

Few examples of TUIs used in well-being is presented in figure: 3. To evaluate the extent to which tangible user interface (TUI) research has been explored and to further investigate whether or not researchers have taken into account all the mentioned areas for exploring TUI, we conducted a systematic review of the literature in accordance with PRISMA guidelines [46]. Our goals were to understand past research trends with respect to mental and physical well-being, therapeutic context, education, and assistive devices. Furthermore, finding their approaches that they applied, their findings, the limitations they have faced and finally future directions that they indicated.

For complete papers, we looked through Google Scholar and the ACM Digital Library. In addition, we looked at Tangible Interfaces for well-being at the IEEE Conference on IEEE Xplore. Our search was limited to words like "well-being approaches", "tangible user interface", "robotic," and "actuated" that could be found in either the title or abstract. Lastly, we didn't include papers that weren't concerned with well-being technologies. Here's an example of how we structured our queries:

[Title: tangible user interface*] OR [Title: tui*] AND [Title: well-being*] OR [Title: mental*] OR [Title: physical*] [Abstract: tangible user interface*] OR [Abstract: tui*] AND [Abstract: well-being*] OR [Abstract: mental*] OR [Abstract: physical*] OR [Abstract: robotic*] OR [Abstract: actuated*]

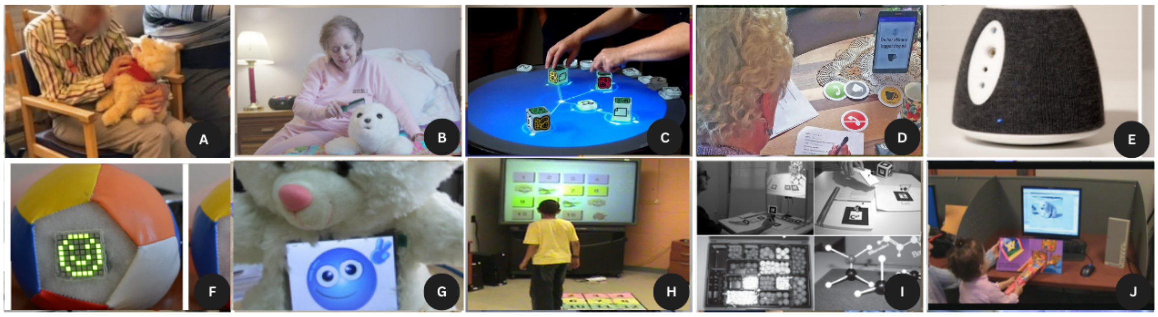

Fig. 3: Examples of TUIs used in well-being: A) Activating Social and Emotional Experiences [32], B) Seal like robot provides Comfort for Alzheimer's Patient [38], C) TUIs for children with Learning Disorders [39], D) Make friends and feel less isolated using TUI cup [40], E) Mobile assistant to support older adults well-being [41], F) Self reporting emotional information using TUI [42], G) Smart toy for emotion regulation [30], H) Enhancing Children's physical well-being [43], I) Learning chemical bonds using TUI [44], and J) Detecting objects using a magic stick [45].

## III. Survey of Tangible User Interfaces

### A. Tangible Interfaces for the Therapeutic Environment

In addition to emphasizing the importance of reciprocity in establishing a relationship with a robotic pet, robotic pets can be utilized to stimulate the social and empathetic experiences of elderly people. All of these robotic companions, like the Golden Pup robot dog, are meant to make people's daily lives more enjoyable. There have recently been four social and emotional benefits—entertainment, relief, support, and enjoyment—that are linked to the interaction and emotional bond between people and companion animals. These benefits are reproduced by pet-like robots. Robot dogs could contribute to improving human well-being by serving as "conversation starters" and playmates who encourage embodied and multimodal engagement, even play between generations. Older people's well-being may be improved, according to prior studies, by interaction with robot dogs [47]. Patients' ability to move and cognition can be restored through sensory stimulation and motion repetition [48], [49], [50]. Therefore, standard occupational therapy (OT) only permits patients to perform monotonous and limited motions with the aid of a therapist. Even though robotic devices are frequently incorporated within therapy, their main purpose in OT remains to increase restricted motion. Robotic devices can enable motion which is repetitive and limited, according to studies [51], [52]. Such motion, however, lowers patients' intrinsic motivation and makes them less interested in OT [53], [48], [54], [55]. To get over these restrictions, game-related researchers have developed motion-based games [48], [56], touch interface games [57], [58], and video games [53], [54] as enjoyable elements to encourage patients to participate in a difficult therapy context. Motion-based games are frequently more appealing to patients than conventional therapy [48], [57].

A seal-like robot PARO [31] used in several research for mental well-being of elderly people with varying levels of dementia. According to research, PARO may have a beneficial impact on users' emotional states and levels of stress as seen in urine hormone levels [59] and EEG readouts [60]. In [36], for assessing the participants' level of involvement(primary, non-primary) with their social and physical environment during therapy sessions, they used PARO, which engaged participants through sound and movement and attempts to give stimulation and increased activity levels. The extent of physical and cognitive impairment varied across the participants. They found that PARO can act as a social mediator for the elderly. They have seen that there were more interactions across all behavioral categories(verbal and physical) over time with the environment and people and by using a conventional statistical t-test [61], the Non-Primary Interactions with PARO were discovered to be significant. They observed variation in participant responses to PARO, indicating that assistive robots need to take into account the many ways in which users can communicate with and interpret them. Thus, they refer to PARO's design's "interpretive flexibility" which can provide users with a variety of ways to interpret and react to their activities. They gathered data analyzing videotape interactions, via on site coded participants' activities and the frequency of all the behaviors.

This finding contradicts the hypothesis that companion robots will drive older persons away from their environment [62]. To understand how the good effects revealed here were accomplished, future work will involve a more in-depth investigation of the video data gathered and of related transcripts. Future research can compare the use of PARO in various therapeutic settings (such as one-on-one therapy, groups of two to three participants), and it can concentrate on how the robot's design's interpretive flexibility contributes to its ability to adapt to various users and usage contexts. Main limitations were few parrticipants.

A similar study [32] described that emphasizes the value of reciprocity in creating a relationship with a robotic pet and makes recommendations for how elderly people might make use of them to improve their psychological and social experiences. They observed how a group of elderly people interacted with a Golden Pup, a commercial robot dog. The purpose of the study was to better understand how elderly participants at day activity centers could be engaged with robotic pets similar to contemporary market smart toys to improve well-being. The Golden Pup has touch and sound-responsive sensors. When touched, "you can feel the heartbeat and it can reply to your verbal commands" [63]. The Golden Pup uses motion sensors to react to touching and cuddling(with puppy-like movements and sounds). The robot simulates the actions and noises of an actual animal, especially with its playful barking and head turns. To better comprehend the first-hand social and emotional experiences of interacting with a robot pet and how they relate to Norman's three described dimensions of experience [64], they presented a case study of a robot dog intervention. They researched how the elderly react to a robot dog's persuasive tactics when they are used in a lighthearted group activity. An interactive play session conducted with both elderly people and young children. Despite this specific context, the study described in the paper exclusively examines the elderly's social and emotional reactions. Although children served as study assistants, the case study's findings focus on how elderly people interacted with the robot dog. In order to create a sense of presence, they employed two different types of questions in both the group activity and the interview. They started by asking people questions about their interactions with animals and their social presence and empathy experiences. The second series of questions focused on empathy, social presence, and social experience. The final section of the questions was based on our observations of the old people's behavior and engagement with the robot dog, which was linked to social presence [65]. The ability to describe feelings in only one word was tested in a second set of questions. They came up with a list of ten adjectives to describe different emotions: happiness, melancholy, surprise, carelessness, emphatic, antipathy, soft, rough, active, and neutral. The third approach included a series of questions that could be simply answered "yes" or "no." These inquiries centered on the strong attachments formed with the Golden Pup following the interaction. The current study's findings show that the elderly were delighted by the robot dog known as the Golden Pup. They interacted with it actively and even played with it by making physical contact. Conversing with it, treating it like a genuine pet. When the robot dog turned its head in the direction where their speech was coming from, the elderly claimed that the Golden Pup understood them and responded to them in a very personal way. This demonstrates the value of making a good first impression: Positive emotional experiences and emotions (such as surprise and interest) lead to more patient interactions on a behavioral level. Through interaction with the robot toy Golden Pup, the robot dog intervention reported in this research encouraged the elderly participants to recall their prior experiences with dogs and other animals. In future, instead of focusing on technology convergence, we should provide more purely natural interfaces and emotional contact. Robotic dogs can then behave more realistically and provide their human pals of all ages with companionship, empathy, and compassion.

The majority of stroke victims experience difficulties with daily tasks as a result of motor, sensory, perceptual, or cognitive impairment [66]. These restrictions not only affect how well daily activities are completed, but also negatively affect social interactions and free time [67], [53], [68], [69].

Because of this, Lee et el. offer a new interactive system in this study called a Shape-changing Robot [70] that has a robotic object that allows for richer physical and kinetic connection (SR). They introduce the innovative Shape-changing Robot (SR), which can change its surface in response to users' motions, including visuo-tactile stimuli, to better understand the impacts of multimodal manipulation and to reflect patients' motivation during therapy. Five post-stroke patients were used in an experiment to assess the suggested SR. This study demonstrates that by drawing patients' attention with actual motion as opposed to the simulated motion, the SR can persuade them to engage physically and emotionally. Additionally, the SR can cause gestural communication. This gesture pattern could inspire stroke victims to move more during rehabilitation.

They classified gestures [71] in order to examine the patients' motions and gestures during the occupational therapy (OT) session in order to fully comprehend their motion where they observed almost 30 different varieties of manipulating gestures. The patients had an implicit belief that they shouldn't discuss their personal opinions with the therapists regarding the OT. In order to promote the active physical manifestation of patients' emotions, they decided to build a new system. They created gaming content for upper-limb rehabilitation, which includes pushing and supporting action along the Z axis as well as reaching and moving motions parallel to the XY plane that are crucial for the regeneration of gross motor abilities.

To investigate the technological acceptance in situ, they carried out an exploratory and qualitative study based on observation and interviews. Based on the ground theory coding technique, the information gathered from the interview and observation was interpreted [72]. There were two phases of the user study. A patient-focused experiment was carried out in-situ in the first phase, and after seeing the video record of the initial experiments, a second method—an expert interview—was used to confirm the applicability of the interface.

Regarding the visuo-tactile sensation of volume created by the three-dimensional shape and the visual effects from the kinetic elements, the patients indicated more satisfaction with the SR than with the virtual content and the touch interface. Additionally, several patients believed that the time they spent playing with the physical mole was less than it actually was. This is an illustration that clearly demonstrates how people prioritize actual interactions over virtual ones. When playing with the actual mole, researchers discovered that the majority of patients spoke with words and gestures as if they were interacting with a genuine pet.

Due to the fact that SR not only promotes physical engagement but also mimetic and communicative behaviors by displaying companionship, these traits may also enhance the therapeutic relationship or emotional recovery.

The effectiveness of a proof-of-concept intervention model with a prototype of smart toys (consisting of clickable ears, vibration motors, movement, and touch detection) in terms of engagement, acceptance, and early subjective markers of emotion regulation effects was examined in [30], which is the first known qualitative in-situ study. The novel aspect of the suggested approach was the delivery of at-home interventions using an interactive object that becomes ingrained in a child's daily interactions to provide in-the-moment regulatory support, without the need for any explicit training on the part of either the child or the parent. It provides a strategy for delivering interventions that fully integrates into children's daily life. The toy is presented to the child as a fearful creature in need of sympathetic treatment from people, such as gentle touching and hugs. The prototype can generate vibration patterns that mimic a heartbeat. The implanted sensors detect a frenzied heartbeat when the toy is taken up, which slows down if the child uses gentle strokes. They specifically intended the prototype interaction to affect two distinct stages: the attentional deployment stage [73], [74] by diverting children's attention away from the emotionally charged environment and toward interacting with the toy, and the response modulation stage [74], [75] by promoting downregulation through enjoyable tactile interaction in a manner similar to the mechanisms thought to underlie the emotion regulatory effects of human–animal interaction. They were curious to see whether children would find the interactions safe, whether they would maintain interest over the course of a week, and whether the toy would become incorporated into their daily activities, including being specifically used for ER. The researcher visited households and interviewed at least one parent in a semi-structured interview(approximately 1 hour) and children were given a prototype, a discovery book that presented the straightforward narrative and recommended playful activities, as well as a basic digital camera to keep at home for 7–8 days because they were interested in investigating natural appropriation in situ. To elicit information from families regarding their children's interaction with the toy, questions were prompted by the pictures the kids took and the tasks they finished in their discovery books.

The following methods were used to collect the data for this study: (1) semi-structured interviews with parents and kids before and immediately after the deployment, (2) pictures kids took while it was happening, and (3) touch interactions that the prototype automatically recorded while it was happening. They only consider a minute to be active if the toy recorded at least 20 separate sensor interactions in that time frame. To prevent accidental touches or simply shifting the item from one location to another.

The majority of kids (10/11) either said they wanted to take the creature with them wherever they went and were eager to show it to family and friends, or they said it themselves. Every child gave their toy a name and cared for it as though it were a living thing with emotions and mental states that needed to be taken into account. Most kids would want to keep the toy longer or would hide it and act like they were unaware of its location, and every kid was sad to give the toy up, according to either the kids or their parents. Every family stated that their children's moods improved after playing with the toy. Additionally, more than half of the parents (7/10) emphasized the sense of responsibility that the backstory gave kids as something that they really liked, which in turn encouraged consistent engagement over the duration of the deployment's week. Children naturally interacted with the toy to calm themselves after going through an emotionally challenging scenario, including a fight with their parents or siblings, or when they wanted to relax, like right before bed. Furthermore, they used the toy when they were in any physical pain as well.

In order to understand the degree of psychological benefits and whether or not they will scale up, future research is required to extend this suggestive results with larger studies assessing the psychological efficacy of the suggested intervention.

Autism-related children may have trouble forming and maintaining relationships with other people. In order to encourage social engagement, studies on autistic children have recently focused on adopting technology, including tabletops, robotics, computer vision, and virtual reality [28], [29]. There is no research that focuses on e-textile paired with music to assist self-regulation and social skill development in kids with autism. Therefore, Nonnis et al demonstrated the concept of Mazi [76], an e-textile sonic tangible user interface (TUI) created with the intention of encouraging fundamental social skills, inspiring spontaneous, independent, and collaborative play, and offering possibilities for these kids to regulate their sensory systems. It was comprised of layers of felted merino wool and polyester padding that covered a soft-play dome. Five hemispheres constructed from covered inflated balancing hedgehogs are added on top of the main body. They attached the hemispheres to a circuit board [77] that was attached to the body's side and covered with a felt sheet. Mazi used a 3.7V Lipo battery for power.

They focused on three design principles: (i) drawing on children's prior experiences and preferences; (ii) supporting self-regulation; and (iii) promoting social interaction. They utilized the shareability principle [78] to promote intuitive use and community.

During the whole investigation, Mazi operated in stand-alone mode. The installation could be moved around the room by the kids, who could also press, squeeze, lie on, and climb on it. Throughout the sessions, basic social skills like turn-taking, eye contact, smiles, interactional starts, sharing of experiences, attention, and places were noted. Even when they weren't near the TUI, the kids used the technology in inventive ways and showed indicators of interest in it and peer interaction. The children were able to behave simultaneously due to the cause-and-effect relationship, and they saw examples of other kids playing together. With grins and spontaneous play, children displayed involvement with the TUI that went beyond the adult's guidance.

Interviews with teachers, teaching assistants, occupational therapists, and parents of the children were conducted during the data collection period, which lasted for approximately two months. They gathered a variety of resources, including the Individual Education Plan, the Performance Scale, the Social Communication, the Emotional Regulation Transactional Support Stages, the Positive Behavior Support Plan, and triggers, likes, and dislikes, as well as their own notes from the observations.

Through USB, Mazi will be powered, which Sadly, there are effects on the mobility aspect of the. This is one of its limitations because of the installation requirements.

### B. Tangible Interfaces for the Physical Well-Being

The extensive use of digital media in virtually every aspect of daily life is a result of current lifestyle trends. Children especially have been impacted by these changes in a number of ways. The young generations' daily lives typically involve playing video games in a regular basis. According to [80] and [81], youngsters who spend too much time using computers, playing video games, or watching television become physically impaired and lead sedentary lifestyles, which leads to a number of social, mental, and medical issues. One key factor endangering the younger generation is obesity, which has recently become an epidemic in many parts of the world, particularly in wealthy nations [82]. In the digital age, sedentary habits are also getting more and more prevalent [83], [84]. Across high and low income

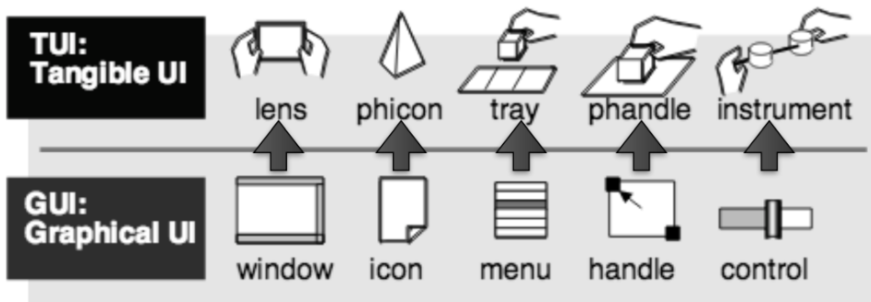


Fig. 4: Transformation of the software/graphical elements into tangible objects [79].

countries, 41.5% of our global populations spend four hours or more each day sitting down [85].

In [35], Shin et al investigated into the idea of a very slowly moving monitor for discrete posture adjustment without noise, vibration, and intrusiveness. Prior research [86] on the use of notification settings for correcting posture has demonstrated that the more intrusive the notification, the more successful it is. It might be used to cause a shift in posture. Although there are worries about the consequences of constant disruptions on the accomplishment of the objective [87], [88]. They set out to research a subtle yet efficient posture correction technique rather than warning users. They proposed that users would alter their posture as a result of following a moving display with their head, neck, and upper body in addition to their eyes. In the attentional background [89], they developed a system for posture recognition and correction. Their system's core idea is to identify unbalanced postures and start the monitor's motion to cause changes in posture. They used a robotic arm to slowly, below the perception threshold [90](A monitor speed of less than 0.5 mm/s is difficult to notice and may be below the threshold of human perception, according to their research.), move a monitor. The robotic monitor moves in the opposite direction and angle from the user's imbalanced posture when they are seated. The display automatically returns to the default recommended position and angle when the user adjusts their posture. According to ergonomic recommendations for sitting at a desk [91], [92], they specified the desired balanced posture. Using that information, they developed a "safe zone" that users had to remain in, in order to avoid triggering the monitor motions. By monitoring a user's eyes, their system calculated their posture [93], [94]. They computed the distance and angle between the eyes and assessed the inclination of the upper body while assuming that the chair was in a fixed position. Using OpenCV 3.3 [95], they created an image processing system. This software creates the Region of Interest (ROI) as a square around the face using a Local Binary Patterns face cascade classifier [96] on a color webcam image. The user's eyes are then located using a Haar feature-based eye cascade classifier [35]. The interaction took place in four steps. The monitor first starts to move in the background of the user's attention as a result of their uneven seating. The monitor then adjusts to balance the posture until the user corrects their own posture. Third, the user makes their first movement and maintains a balanced posture. Finally, the monitor then returns to its default settings. This paper makes three contributions: 1) the design of an actuated monitor that moves below the perception threshold, 2) a study of how and when users react to extremely slow motions, and 3) an evaluation of the interaction's efficacy in a real-world scenario with a variety of activities spread out over several hours. They discovered that most individuals quickly and unobtrusively adjusted their posture. Participants adjusted their posture while still typing or reading without any disruption. Even though the fast reset could be intrusive, they implemented it to reduce pain for extreme positions and angle shifts. They discovered it was neither obtrusive nor did it interfere with their work; rather, it served as a clear cue to adjust their posture. They think it can also be used in other furniture pieces, such desks, chairs, and kitchen counters, as well as in other fields, like helping patients who are lying in bed or using slow assistive robots for precise manipulation in fields like surgery or jewelry creation. Since their current system only had one default setting, it ignored the content displayed on the screen. They suggested that the system would learn several good monitor postures and support users' posture in an adaptable manner by taking into account changes in tasks, text size, and screen usage.

In another similar kind of study [97], in order to decrease the risks of prolonged sedentary behaviors, which are linked to poor overall health [98], Kim et al proposed robotic furniture (the Haunted Desk) that uses robotic technology to influence non-volitional behavior with low-cost, featuring an anti-pinch safety feature, possibilities for micro-height adjustment, and a straightforward haptic movement warning. Though traditional sit-stand desks may help to reduce inactive time and maybe decrease health risk factors [99], one-third of sit-stand desk owners only use the stand-up function occasionally [100]. Due to this, they suggest the Haunted Desk, which manages standing and sitting transitions automatically, relieving users of the pressure of making decisions and encouraging healthy movement throughout the workday. Initial user impressions were gathered based on 7 points: likeability, safety, productivity, stress, and how recommendable it is, both in-the-moment (during the interactions) and retrospectively via a semi-structured brief interview, and they compared with those for a manual desk. Randomly, one half of the participants used the manual desk first, followed by the autonomous desk, whereas the other half used the desks in the reverse sequence. Although users' retrospective analyses revealed bi-modal distributions, in-the-moment ratings across the autonomous and manual desks were identical.

For future research, the sit-stand desks will be used for weeks rather than minutes in a longitudinal research where participants will actually work at them. They proposed using a 30-minute break between sitting and standing in place of the standard 5-minute breaks. They are curious to know if a user's desired level of autonomy—whether it be the autonomous condition in which the desk automatically changes height or manual configuration—leads to longer and more regular use of the sit-stand desks.

According to [80] and [81], children who use computers, electronic devices, and televisions excessively become physically inactive and lead sedentary lifestyles, which leads to a number of social, mental, and medical issues. One significant factor endangering the younger generation is obesity, which has recently become an epidemic in many parts of the world, particularly in wealthy nations [82]. Therefore, Karime et al conducted a study where they introduced MeMaPads [43], an exergaming(exercising and gaming) system that simultaneously encourages learning and exercise through play. It consists of several sensory mounted pads that are used to interact with two software games created specifically to instruct, amuse, and promote physical activity. Exergames, also known as serious games, are currently a popular research topic among academics because to their significant positive effects on the future welfare of society. The DDR from Konami is one of the most well-known of these instruments [101]. The Nintendo Wii Sports [102], which employs a physical remote control combined with an accelerometer to help monitor the user's hand movements, is another common device. The Eye Toy game series [103] from the Playstation 2 is another example. It employs a camera to capture the user's movements, which are subsequently translated into actions. They carried out the study because one major drawback of the majority of exergames currently available is that they primarily concentrate on enhancing kids' physical health without taking into account their mental wellness [104].

They suggest a multimedia exergaming and educational system in this study that takes into account the users' physical and mental health. MeMaPads is a padding system that uses a specific quantity of tiles to interact with two games—a math game and a memory game. However, by responding to some simple addition, subtraction, and multiplication questions, as well as other basic arithmetic problems, the math game enables kids to develop their critical thinking abilities. Both games allow parents to participate in their children's education, which has been included into the personalization features of the games. Finally, to examine the system's effects on kids' cognitive development and to find out if there were any issues, they conducted both quantitative and qualitative evaluation.

The Pressure Sensory Module, Signal Processing and Detection, Communication, Game Engine, Player's Profile, and Presentation Modules are all parts of the overall system architecture. C has been used to implement the video game software in a Visual Studio 2008 environment. They have used the Microsoft Speech Engine's API for the spoken spelling of texts and messages. On the other hand, 16 force resistive square-shaped sensors were incorporated into the mat's design. Additionally, they performed all necessary signal conversions and sensory computations using an Arduino Uno microcontroller. They used a BlueSmirf Bluetooth chip with a 9600 kbps baud rate for communication. A second Bluetooth dongle was connected to the PC running the game's software.

Their future work will involve expanding the system's capabilities, such as by including an avatar in the games that would move in accordance with the player's movements on the control pads. They think that adding this functionality will improve the user's gameplay and make it more engaging. Additionally, they intend to analyze how the system affects the kids' fitness in order to conduct more quantitative evaluations.

### *C. Tangible User Interfaces as an Assistive device*

From 17.4% in 2014 to 25.6% in 2030, the population over 65 will grow rapidly during the coming years [105]. Technological advances may significantly contribute to good aging by supplying the knowledge and resources needed to enable longer and more satisfying independent lives at home. However, creating digital tools to support healthy lives can be difficult since they must satisfy the diverse requirements and preferences of older persons while avoiding stigmatization and having user-friendly, intuitive interfaces. In terms of the adoption of computer-based technologies, there is also strong evidence that older people and younger generations are in opposition [106]. According to current trends, computers and the internet are being used by people of all ages, hence it is essential to create technology that is accessible to all age groups [107]. According to studies, there is a growing generational divide between older people and younger people, which makes older people feel isolated and detached. Additionally, because of their cognitive impairment, elderly also feel a stronger sense of dependence [108].

Based on physiological and behavioral data collected via wearable and ambient sensors, as well as through various talks with the user, they proposed the construction of a conversational e-coach in [20] for improving well-being in four distinct areas—physical exercise, nutrition, social interaction, and cognition. The delivery of "advice and coaching" provided by an intelligent system that uses cloud data analysis and decision support logic. The user will be able to communicate with the conversational agent digitally through a smartphone chat app and physically through a tangible object. The Nestore platform was created and developed using a codesign approach in partnership with partners from 4 different nations: UK, Spain, The Netherlands, and Italy, in order to better satisfy the needs and expectations of users. In order to encourage self-reflection, the tangible coach may serve as the tangible interface and represent both the e-coach conversational agent and the user's progress toward the objective through data physicalization [109]. Through the use of text-to-speech and speech-to-text APIs, the physical coach interface offers audio communication with users utilizing the same conversational agent architecture as the chatbot. The Chatbot is a text-based chatbot where the user can communicate by text or media (such as photos, emoticons, etc.). Additionally, the e-coach conversation's personality must be adjusted in accordance with the requirements and preferences of the users. The e-coach discussion is created in English and manually translated into Spanish, Dutch, and Italian, modifying them to local traditions and idioms.

The Nestore conversational agent's logic is made up of three main parts: RASA Core and NLU for intent recognition and Natural Language Understanding (NLU), a Node.js server for managing the logic of the conversation, and a second server for dispatching the messages to the various interfaces based on context information and user preferences. The Nestore mobile app, available for iOS and Android, has a chatbot interface. In fact, they favored employing a standalone app created with the Ionic cross-platform development framework over using existing messaging services (like Facebook Messenger), which frequently require signing up for external social networks to optimize the chatbot's accessibility. Its physical manifestation can either be created entirely from scratch using a Raspberry Pi or centered around a tablet with Arduino add-ons for sensing and actuation. An external module did semantic analysis on user messages in order to gauge the user's attitude and adjust the conversation as necessary.

The coach is also supposed to send encouraging messages to the elderly and create a realistic motivating friendly environment. According to preliminary findings, older adults prefer a positive and supportive coach who can inspire them to take care of themselves rather than a directive one.

Bhayana et al developed Sahayak, a method of assistance for the elderly that looks at how technology might increase younger generations' involvement in their lives, in [21]. They looked at how Sahayak helps elderly to maintain their independence and maintain relationships with their loved ones. It uses sensors to track steps taken, calories burned, temperature, sleep patterns, breathing, and location. It can also detect falls and track heart rate, blood pressure, and breathing. Additionally, it enables family members to learn about the daily routines of their parents' and grandparents' dietary preferences, physical welfare, and medical conditions. Finally, it links the device and companion application after processing the data. If a serious medical condition arises, Sahayak features a built-in emergency mechanism that notifies the closest hospital and emergency services. The initial step in their design approach involved learning about the issue at hand and acquiring an understanding of the needs, opinions, and expectations of users. The following phase was to get qualitative and quantitative feedback about our system from each of the user groups and then iterate our design to make it better suited to the user. Elderly and their family members were interviewed in semi-structured and unstructured contexts.

Caregivers for children with cancer are typically mothers [70] and may share a home with other caregivers. Over half of all caregivers showed clinically significant levels of depression, according to a study [110]. In [110], Fuentes et el. researched the requirements of these mothers in light of their unique circumstances, which include living in a community of caregivers, having a portion of their families live in different cities or countries, and having to manage the demands of caring for their children's physical and emotional needs. They then created the Ohana Bear, a tangible user interface (TUI) [110] that caregivers may use to express and transmit their emotions to their loved ones or doctors and encourage emotional well-being and self-reflection. Additionally, to help caretakers track their feelings and possibly share them with their families, they created the Ohana Bear, which enables them to record their emotions. Another promising sign that Ohana would be a non-intrusive addition to the mothers' relaxation routines is the fact that it was a teddy bear and so encouraging playfulness and relaxation, helping a user forget that she was "trying" to convey her emotions. The development and evaluation of Ohana, a tangible user interface that enables caregivers to simply express their emotions to their families and doctors, as well as reflect on their emotional well-being and needs, are presented in this paper along with a qualitative study to understand caregivers' emotional well-being. The screen is incorporated within the bear's tummy. A button on each of the bear's hands enables user interaction. Touching the screen also enables you to capture your emotions. An emotional representation of an image is shown on the screen. The emotion shown varies if the left hand of the bear is pressed. With each button press, the six different emotions that are displayed on the screen change. The emotion is saved if the screen is touched, and a message verifying this appears. This stores the data and contextual information on the SD card. The screen shows a straightforward graph summarizing the saved emotions whenever the bear's right hand is pressed. They conducted six semi-structured interviews with mothers who serve as the primary caregivers for their children receiving cancer treatment and reside at housing for caregivers in Chile to better understand the requirements of caregivers. Users claimed that they were able to utilize the device easily and with ease upon learning how to use it.

Their future work will include expanding the system's capabilities, such as by including a wireless speaker inside the Magic Stick to lessen the commotion caused by numerous sticks being used at once. Additionally, they want to improve children's education by combining multilingualism. They also intend to include haptic capabilities to test the feasibility of the system for interaction.

## IV. Subsequent Work

### A. Tangible Interfaces for an Educational Purpose

Globally, there is a serious problem with illiteracy. According to UNESCO, almost 20% of people worldwide are illiterate [111]. According to the NAAL, the most recent and continuous measure of adult literacy, 14% of Americans are illiterate, 32 million cannot read the directions on a prescription bottle, and 50 million cannot read at a level above the fifth grade [112]. Multimedia educational systems, according to research, promise to make learning considerably simpler, more practical, and hence more efficient [113]. In light of this, there has been an increasing demand to improve the edutainment environment using multimedia technologies that seamlessly support both education and fun [114], [115]. Studies have also shown that extremely young children as young as 6 months old can comprehend brief stories or words that are illustrated [116].

Because of the "inherent fascination" robots hold for most children, robots typically find a compelling use in child-focused domains [117]. In this way, children gain experimental and exploratory skills that support a variety of learning methods [21]. In a world that is becoming more and more digital, literacy can be developed in a physical, digital, and contextual setting that is evocative of the picture book being read. Schafer et al built LIT ROOM [118], which is an intelligent, fine-tunable suite of architectural-robotic objects dispersed at room-scale in a public library setting, inspired by ideas of embodied engagement. The proposed LIT ROOM has a variety of mixed-technology robots, including a wall-mounted track for guiding mobile robots surfaces or items; a set of similar modular robotic building blocks, each outfitted with displays and sensors; and a variety of various modular robotic building elements, passive or movable. Additionally, there are reading tables in the installation that can hold six children and one adult guide. These tables has interactive surfaces that support, in particular, the modular robotic blocks used as tangible interfaces (i.e., phicons [63]) for fine-tuning the system's intelligence. ICT components (such as sensors, a digital projector, lighting, audio, and a printer) and more traditional environmental-design elements are integral to the system. Unlike these earlier attempts, the LIT ROOM places a greater emphasis on a child's fun interactions with the people they meet, the physical and digital objects they use, and the digital-physical environment that frames the event. After leaving the library, children can continue their LIT ROOM experience on an interactive website. The LIT ROOM website would also offer resources that replicate the LIT ROOM experience by offering tasks, courses, and other relevant content.

Children are asked to comment on what makes an engaging LIT ROOM during Phase 1. Then they assess how kids, aged 4 to 8, define and use this digital-physical suite by showing them low-fidelity "architectural robotic" artifacts in a library setting. The relationships between the kids were assessed using a number of proven techniques, such as talk-aloud procedures, active interventions, and observations [119]. In Phase 2, the team iteratively creates and assesses (1) the suite (as a fully functional environment) and (2) the two associated outreach mechanisms in response to the feedback obtained from the collaborative exploration. The fully operational environment was again assessed using the same techniques as in Phase 1. Furthermore, parents and educators are given the chance to evaluate the LIT KIT, and the interactive website includes web analytics and a poll to assess the value of these tools.

For future work, a "LIT KIT" will be created for parents and educators to utilize in the classroom and at home. This will enhance the interactive experience of the LIT ROOM. The KIT might use a cheap microcontroller as its computer so that no laptop or desktop computer is needed to move the robotic component of the LIT ROOM to the school or home. Furthermore, the KIT might contain the identical Sifteo [120] cubes that are utilized in-situ to replicate the word-module component of the LIT ROOM in homes and classrooms. Future research will concentrate on creating a working prototype to test the essential elements of the LIT ROOM on test subjects (young readers with an adult guide) in a lab setting.

Karime et el. introduce the Magic Stick [45], an educational toy that helps kids learn about new things by giving them names and visual descriptions of those things. By simply adding RFID tags to these objects, parents or teachers can choose the objects they want their students to learn about. Then, using a user-friendly GUI, users may modify the kind of data and visualizations connected to these entities.

They have made a contribution to this paper by designing a TUI for considerably younger children who are still in the very early stages of development, as addition to one for children aged 4 and up. Through the use of audio and visual representations, their suggested approach aims to entertain and educate kids. Children can learn the names of new items in their environment by using the TUI that they called the Magic Stick. Parents or teachers can select the items they want their kids or students to learn about and quickly tag them with an RFID tag.

They created an inductor with a predetermined number of turns that serves as an antenna and creates a magnetic field around the RFID to increase reading distance (up to 25 cm). Through Bluetooth, a wireless connection is established between the stick and the computer. A natural engagement with the tool is made possible by the proximity sensor activating the Stick. Furthermore, they have implemented the lexical WordNet filtering method described in [121] in order to distinguish between offensive and non-offensive content. The Media Selection Service and Media Presentation Service modules will handle the search and display of appropriate visual material connected to the detected tag. The ID Mapping Service module is in charge of matching the tag identification with the necessary descriptions previously stored in the database and passing this information to the modules. The Media Selection Service asks the webservice for the relevant images after getting the mapped data. Additionally, in the behavior described in [121], the process of filtering offensive images takes place at this stage. Finally, the Media Presentation Service module's defined algorithm is used to display the anticipated output media.

A BlueSmirf Gold Bluetooth chip and Core 12-RFID module were used to implement the Magic Stick. The tool's switch has been constructed from a very simple proximity sensor that is connected to a transistor. The RFID reader is equipped with an indicator led that flashes to show when an ID tag has been detected. A 9 V battery coupled to a voltage regulator that provides + 5 V to the entire circuit powers the stick. On the computer side, the software program was created on a Windows XP platform with Visual Studio 2005 (C). For sound initiation, they used the Microsoft Speech Engine API.

## V. Conclusion

The use of tangible devices to enhance well-being at present is a relatively unexplored area of study. More thorough investigations must be undertaken to support the claims that tangible interfaces have the ability to enable such technology to be altered, scaled, and culturally adapted to serve the global population. SARs, applications, sensing devices, tools for modifying behavior, and real-time intervention devices are just a few of the various ways that have been thought of to sense and enhance mental and physical well-being. This paper presents the tangible user interfaces(TUIs) used in assistive devices, educational purposes, therapy, and in other human-computer interactions in modern technologies. The goal of the interface is to offer a suitable medium for human well-being in both psychological and physical domains so that they can interact with the computer more effectively and spontaneously. Even if the majority of the suggested tools are still in their beginnings, some of them have advanced due to the use of contemporary technologies. The features that should be added to an interface to improve it are described based on this review. Despite the fact that the majority of researchers stated that their findings lacked statistical depth because of fewer participants or study data, this field still has a lot of potentials if we can efficiently use the resources at our disposal. This work should be useful to researchers who are passionate about creating better, more effective, and efficient interfaces for human-computer interactions that promote well-being.

## References


[1] C.-M. Wang, S.-M. Tseng, and C.-S. Huang, "Design of an interactive nostalgic amusement device with user-friendly tangible interfaces for improving the health of older adults," in *Healthcare*, vol. 8, no. 2. MDPI, 2020, p. 179.

[2] M. V. Law, N. Dhawan, H. Bang, S.-Y. Yoon, D. Selva, and G. Hoffman, "Side-by-side human–computer design using a tangible user interface," in *International Conference on-Design Computing and Cognition*. Springer, 2018, pp. 155–173.

[3] I. Bataille, "Tangible user interfaces in the smart home environment," 2020.

[4] J. Harris, J. Young, N. Sultanum, P. Lapides, E. Sharlin, and M. C. Sousa, "Designing snakey: a tangible user interface supporting well path planning," in *IFIP Conference on Human-Computer Interaction*. Springer, 2011, pp. 45–53.

[5] Z. Zhou, A. D. Cheok, J. Pan, and Y. Li, "Magic story cube: an interactive tangible interface for storytelling," in *Proceedings of the 2004 ACM SIGCHI International Conference on Advances in computer entertainment technology*, 2004, pp. 364–365.

[6] S. Cuendet, J. Dehler-Zufferey, G. Ortoleva, and P. Dillenbourg, "An integrated way of using a tangible user interface in a classroom," *International Journal of Computer-Supported Collaborative Learning*, vol. 10, no. 2, pp. 183–208, 2015.

[7] W. K. Bong, W. Chen, and A. Bergland, "Tangible user interface for social interactions for the elderly: a review of literature," *Advances in Human-Computer Interaction*, vol. 2018, 2018.

[8] T. Chandrasekera and S.-Y. Yoon, "The effect of tangible user interfaces on cognitive load in the creative design process," in *2015 IEEE International Symposium on Mixed and Augmented Reality-Media, Art, Social Science, Humanities and Design*. IEEE, 2015, pp. 6–8.

[9] A. T. Adams, E. L. Murnane, P. Adams, M. Elfenbein, P. F. Chang, S. Sannon, G. Gay, and T. Choudhury, "Keppi: A tangible user interface for self-reporting pain," in *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, 2018, pp. 1–13.

[10] S. Brave, H. Ishii, and A. Dahley, "Tangible interfaces for remote collaboration and communication," in *Proceedings of the 1998 ACM conference on Computer supported cooperative work*, 1998, pp. 169–178.

[11] S. Aldawood, F. Aleissa, R. Alnasser, A. Alfaris, and A. Al-Wabil, "Interaction design in a tangible collaborative decision support system: the city schema dss," in *International Conference on Human-Computer Interaction*. Springer, 2014, pp. 508–512.

[12] B. Jones, A. Tang, C. Neustaedter, A. N. Antle, and E.-S. McLaren, "Designing a tangible interface for manager awareness in wilderness search and rescue," in *Companion of the 2018 ACM Conference on Computer Supported Cooperative Work and Social Computing*, 2018, pp. 161–164.

[13] E. Ras, V. Maquil, M. Foulonneau, and T. Latour, "Empirical studies on a tangible user interface for technology-based assessment: Insights and emerging challenges," *International Journal of e-Assessment (IJEA), CAA*, vol. 201, no. 241, pp. 35–41, 2012.

[14] K. Woodward, E. Kanjo, D. Brown, T. M. McGinnity, B. Inkster, D. MacIntyre, and T. Tsanas, "Beyond mobile apps: a survey of technologies for mental well-being," *IEEE Transactions on Affective Computing*, 2020.

[15] R. Suzuki, A. Karim, T. Xia, H. Hedayati, and N. Marquardt, "Augmented reality and robotics: A survey and taxonomy for ar-enhanced human-robot interaction and robotic interfaces," in *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, 2022, pp. 1–32. [Online]. Available: https://doi.org/10.1145/1122445.1122456

[16] C. M. health Association. Connection Between Mental and Physical Health, year = 2022, url = https://ontario.cmha.ca/documents/connection-between-mental-and-physical-health/: :text=The

[17] A. Collins and R. Halverson, "The second educational revolution: Rethinking education in the age of technology," *Journal of computer assisted learning*, vol. 26, no. 1, pp. 18–27, 2010.

[18] M. S. Horn, R. J. Crouser, and M. U. Bers, "Tangible interaction and learning: the case for a hybrid approach," *Personal and Ubiquitous Computing*, vol. 16, no. 4, pp. 379–389, 2012.

[19] L. Dubuc and D. Edge, "Tuis to ease: tangible user interfaces in assistive technology," in *Proceedings of the 3rd Cambridge Workshop on Universal Access and Assistive Technology (CWUAAT 2006). Citeseer, Cambridge*. Citeseer, 2006.

[20] M. El Kamali, L. Angelini, M. Caon, G. Andreoni, O. A. Khaled, and E. Mugellini, "Towards the nestore e-coach: a tangible and embodied conversational agent for older adults," in *Proceedings of the 2018 ACM International Joint Conference and 2018 International Symposium on Pervasive and Ubiquitous Computing and Wearable Computers*, 2018, pp. 1656–1663.

[21] R. Bhayana, K. Agrawal, M. Aggarwal, R. Devgon, and R. Kar, "Sahayak: An application for social and physical well-being for the elderly," in *IndiaHCI'20: Proceedings of the 11th Indian Conference on Human-Computer Interaction*, 2020, pp. 124–129.

[22] J. Aljaam, A. Jaoua, S. AlHazbi, A. Hasnah, A. Karime, and A. A. Elsaddik, "An assistive computerized system with tangible user interfaces for children with moderate intellectual and learning disabilities," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 6, no. 2011, 2011.

[23] M. Zajc and A. Istenic Starcic, "Potentials of the tangible user interface (tui) in enhancing inclusion of people with special needs in the ict-assisted learning and e-accessibility," in *KES International Symposium on Agent and Multi-Agent Systems: Technologies and Applications*. Springer, 2012, pp. 261–270.

[24] A. Al Mahmud and A. I. Soysa, "Poma: A tangible user interface to improve social and cognitive skills of sri lankan children with asd," *International Journal of Human-Computer Studies*, vol. 144, p. 102486, 2020.

[25] M. D. Lozano, V. M. Penichet, B. Leporini, and A. Fernando, "Tangible user interfaces to ease the learning process of visually-impaired children," 2018.

[26] K. Sitdhisanguan, N. Chotikakamthorn, A. Dechaboon, and P. Out, "Using tangible user interfaces in computer-based training systems for low-functioning autistic children," *Personal and Ubiquitous Computing*, vol. 16, no. 2, pp. 143–155, 2012.

[27] J. Santos, L. M. Jesus, M. Vairinhos, and J. Rodriguez, "Tangible user interface for homework for children with communication disorders," in *2019 14th Iberian Conference on Information Systems and Technologies (CISTI)*. IEEE, 2019, pp. 1–6.

[28] H. E. Andreae, P. M. Andreae, J. Low, and D. Brown, "A study of auti: a socially assistive robotic toy," in *Proceedings of the 2014 conference on Interaction design and children*, 2014, pp. 245–248.

[29] A. Bhattacharya, M. Gelsomini, P. Pérez-Fuster, G. D. Abowd, and A. Rozga, "Designing motion-based activities to engage students with autism in classroom settings," in *Proceedings of the 14th international conference on interaction design and children*, 2015, pp. 69–78.

[30] N. Theofanopoulou, K. Isbister, J. Edbrooke-Childs, P. Slovák *et al.*, "A smart toy intervention to promote emotion regulation in middle childhood: Feasibility study," *JMIR mental health*, vol. 6, no. 8, p. e14029, 2019.

[31] Wikipedia. Paro (robot), year = 2022, url = https://cutt.ly/mCz5ESv,.

[32] P. Ihamäki and K. Heljakka, "Robot dog intervention with the golden pup: Activating social and empathy experiences of elderly people as part of intergenerational interaction," in *Proceedings of the 54th Hawaii International Conference on System Sciences*, 2021, p. 1888.

[33] O. Boubaker, "Medical robotics," *Control Theory in Biomedical Engineering*, pp. 153–204, 2020.

[34] J. Broekens, M. Heerink, H. Rosendal *et al.*, "Assistive social robots in elderly care: a review," *Gerontechnology*, vol. 8, no. 2, pp. 94–103, 2009.

[35] J.-G. Shin, E. Onchi, M. J. Reyes, J. Song, U. Lee, S.-H. Lee, and D. Saakes, "Slow robots for unobtrusive posture correction," in *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 2019, pp. 1–10.

[36] S. Šabanović, C. C. Bennett, W.-L. Chang, and L. Huber, "Paro robot affects diverse interaction modalities in group sensory therapy for older adults with dementia," in *2013 IEEE 13th international conference on rehabilitation robotics (ICORR)*. IEEE, 2013, pp. 1–6.

[37] E. Riedenklau, "Development of actuated tangible user interfaces: New interaction concepts and evaluation methods," 2016.

[38] O. C. M. Hospice. Robotic Seal Provides Comfort for Alzheimer's Patient, year = 2018, url = https://www.communitymercyhospice.org/robotic-seal-provides-comfort-for-alzheimers-patient/,.

[39] N. Pookkottuvariam. Tangible User Interfaces for Children with Learning Disorders, year = 2019, url = https://nivedithaartist.medium.com/tangible-user-interfaces-for-children-with-learning-disorders-ec083378de6a,.

[40] oslome. Make new friends and avoid feeling isolated using a tangible cup, year = 2020, url = https://www.oslomet.no/en/research/featured-research/make-new-friends-and-avoid-to-feel-isolated-using-a-tangible-cup,.

[41] M. El Kamali, L. Angelini, M. Caon, O. A. Khaled, E. Mugellini, N. Dulack, P. Chamberlin, C. Craig, and G. Andreoni, "Nestore: Mobile chatbot and tangible vocal assistant to support older adults' wellbeing," in *Proceedings of the 2nd Conference on Conversational User Interfaces*, 2020, pp. 1–3.

[42] C. Fuentes, I. Rodríguez, and V. Herskovic, "Emoball: a study on a tangible interface to self-report emotional information considering digital competences," in *Ambient Intelligence for Health*. Springer, 2015, pp. 189–200.

[43] A. Karime, B. Hafidh, A. Khaldi, J. M. Aljaam, and A. El Saddik, "Memapads: Enhancing children's well-being through a physically interactive memory and math games," in *2012 IEEE International Instrumentation and Measurement Technology Conference Proceedings*. IEEE, 2012, pp. 2563–2566.

[44] M. Fjeld, J. Fredriksson, M. Ejdestig, F. Duca, K. Bötschi, B. Voegtli, and P. Juchli, "Tangible user interface for chemistry education: comparative evaluation and re-design," in *Proceedings of the SIGCHI conference on Human factors in computing systems*, 2007, pp. 805–808.

[45] A. Karime, M. A. Hossain, W. Gueaieb, and A. El Saddik, "Magic stick: a tangible interface for the edutainment of young children," in *2009 IEEE International Conference on Multimedia and Expo*. IEEE, 2009, pp. 1338–1341.

[46] A. Liberati, D. G. Altman, J. Tetzlaff, C. Mulrow, P. C. Gøtzsche, J. P. Ioannidis, M. Clarke, P. J. Devereaux, J. Kleijnen, and D. Moher, "The prisma statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration," *Journal of clinical epidemiology*, vol. 62, no. 10, pp. e1–e34, 2009.

[47] L. Huang, J. Picart, and D. Gillan, "Toward a generalized model of human emotional attachment," *Theoretical Issues in Ergonomics Science*, vol. 22, no. 2, pp. 178–199, 2020.

[48] G. Alankus, R. Proffitt, C. Kelleher, and J. Engsberg, "Stroke therapy through motion-based games: a case study," *ACM Transactions on Accessible Computing (TACCESS)*, vol. 4, no. 1, pp. 1–35, 2011.

[49] F. Freyer, M. Reinacher, G. Nolte, H. R. Dinse, and P. Ritter, "Repetitive tactile stimulation changes resting-state functional connectivity—implications for treatment of sensorimotor decline," *Frontiers in human neuroscience*, vol. 6, p. 144, 2012.

[50] C. E. Lang, J. R. MacDonald, and C. Gnip, "Counting repetitions: an observational study of outpatient therapy for people with hemiparesis post-stroke," *Journal of Neurologic Physical Therapy*, vol. 31, no. 1, pp. 3–10, 2007.

[51] S. E. Fasoli, H. I. Krebs, J. Stein, W. R. Frontera, and N. Hogan, "Effects of robotic therapy on motor impairment and recovery in chronic stroke," *Archives of physical medicine and rehabilitation*, vol. 84, no. 4, pp. 477–482, 2003.

[52] P. S. Lum, C. G. Burgar, P. C. Shor, M. Majmundar, and M. Van der Loos, "Robot-assisted movement training compared with conventional therapy techniques for the rehabilitation of upper-limb motor function after stroke," *Archives of physical medicine and rehabilitation*, vol. 83, no. 7, pp. 952–959, 2002.

[53] G. Alankus, A. Lazar, M. May, and C. Kelleher, "Towards customizable games for stroke rehabilitation," in *Proceedings of*

the SIGCHI conference on human factors in computing systems*, 2010, pp. 2113–2122.

[54] M. Balaam, S. Rennick Egglestone, G. Fitzpatrick, T. Rodden, A.-M. Hughes, A. Wilkinson, T. Nind, L. Axelrod, E. Harris, I. Ricketts *et al.*, “Motivating mobility: designing for lived motivation in stroke rehabilitation,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2011, pp. 3073–3082.

[55] J. W. Burke, M. McNeill, D. K. Charles, P. J. Morrow, J. H. Crosbie, and S. M. McDonough, “Optimising engagement for stroke rehabilitation using serious games,” *The Visual Computer*, vol. 25, no. 12, pp. 1085–1099, 2009.

[56] F. Anderson, M. Annett, and W. F. Bischof, “Lean on wii: physical rehabilitation with virtual reality wii peripherals,” *Stud Health Technol Inform*, vol. 154, no. 154, pp. 229–34, 2010.

[57] M. Annett, F. Anderson, D. Goertzen, J. Halton, Q. Ranson, W. F. Bischof, and P. Boulanger, “Using a multi-touch tabletop for upper extremity motor rehabilitation,” in *Proceedings of the 21st Annual Conference of the Australian Computer-Human Interaction Special Interest Group: Design: Open 24/7*, 2009, pp. 261–264.

[58] C. Boulanger, A. Boulanger, L. de Greef, A. Kearney, K. Sobel, R. Transue, Z. Sweedyk, P. H. Dietz, and S. Bathiche, “Stroke rehabilitation with a sensing surface,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2013, pp. 1243–1246.

[59] K. Wada and T. Shibata, “Living with seal robots—its sociopsychological and physiological influences on the elderly at a care house,” *IEEE transactions on robotics*, vol. 23, no. 5, pp. 972–980, 2007.

[60] K. Wada, T. Shibata, T. Musha, and S. Kimura, “Effects of robot therapy for demented patients evaluated by eeg,” in *2005 IEEE/RSJ international conference on intelligent robots and systems*. IEEE, 2005, pp. 1552–1557.

[61] Wikipedia. Student’s t-test), year = 2022, url = https://en.wikipedia.org/wiki/Student

[62] S. Turkle, *Alone together: Why we expect more from technology and less from each other*. Hachette UK, 2017.

[63] H. Ishii and B. Ullmer, “Tangible bits: towards seamless interfaces between people, bits and atoms,” in *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems*, 1997, pp. 234–241.

[64] D. A. Norman, *Emotional design: Why we love (or hate) everyday things*. Civitas Books, 2004.

[65] A. Batliner, S. Biersack, and S. Steidl, “The prosody of pet robot directed speech: evidence from children,” 2006.

[66] L. Mercier, T. Audet, R. Hébert, A. Rochette, and M.-F. Dubois, “Impact of motor, cognitive, and perceptual disorders on ability to perform activities of daily living after stroke,” *Stroke*, vol. 32, no. 11, pp. 2602–2608, 2001.

[67] B. Ahlsiö, M. Britton, V. Murray, and T. Theorell, “Disablement and quality of life after stroke.” *Stroke*, vol. 15, no. 5, pp. 886–890, 1984.

[68] G. Kwakkel, “Impact of intensity of practice after stroke: issues for consideration,” *Disability and rehabilitation*, vol. 28, no. 13-14, pp. 823–830, 2006.

[69] I. Treger, J. Shames, S. Giaquinto, and H. Ring, “Return to work in stroke patients,” *Disability and rehabilitation*, vol. 29, no. 17, pp. 1397–1403, 2007.

[70] N. Lee, Y. H. Lee, J. Chung, H. Heo, H. Yang, K. S. Lee, H. Ryu, S. Jang, and W. Lee, “Shape-changing robot for stroke rehabilitation,” in *Proceedings of the 2014 conference on Designing interactive systems*, 2014, pp. 325–334.

[71] M. Karam *et al.*, “A taxonomy of gestures in human computer interactions,” 2005.

[72] B. G. Glaser and J. Holton, “Discovery of grounded theory,” 1967.

[73] A. Aldao, G. Sheppes, and J. J. Gross, “Emotion regulation flexibility,” *Cognitive Therapy and Research*, vol. 39, no. 3, pp. 263–278, 2015.

[74] S. Turkle, “Authenticity in the age of digital companions,” *Interaction studies*, vol. 8, no. 3, pp. 501–517, 2007.

[75] S. M. Rabbitt, A. E. Kazdin, and B. Scassellati, “Integrating socially assistive robotics into mental healthcare interventions: Applications and recommendations for expanded use,” *Clinical psychology review*, vol. 35, pp. 35–46, 2015.

[76] A. Nonnis and N. Bryan-Kinns, “Mazi: a tangible toy for collaborative play between children with autism,” in *Proceedings of the 18th ACM International Conference on Interaction Design and Children*, 2019, pp. 672–675.

[77] B. Conductive. Bare Conductive), year = 2022, url = https://www.bareconductive.com/,.

[78] E. Hornecker, P. Marshall, and Y. Rogers, “From entry to access: how shareability comes about,” in *Proceedings of the 2007 conference on Designing pleasurable products and interfaces*, 2007, pp. 328–342.

[79] C. C. Andrea Conci. Introduction to Tangible User Interfaces, year = 2008, url = https://tinyurl.com/5n6cd976,.

[80] S. Yang, B. Smith, and G. Graham, “Healthy video gaming: Oxymoron or possibility?” *Innovate: Journal of Online Education*, vol. 4, no. 4, 2008.

[81] P. Hardus, C. Van Vuuren, D. Crawford, and A. Worsley, “Public perceptions of the causes and prevention of obesity among primary school children,” *International journal of obesity*, vol. 27, no. 12, pp. 1465–1471, 2003.

[82] D. Nemet, S. Barkan, Y. Epstein, O. Friedland, G. Kowen, and A. Eliakim, “Short-and long-term beneficial effects of a combined dietary–behavioral–physical activity intervention for the treatment of childhood obesity,” *Pediatrics*, vol. 115, no. 4, pp. e443–e449, 2005.

[83] L. Straker and S. E. Mathiassen, “Increased physical work loads in modern work–a necessity for better health and performance?” *Ergonomics*, vol. 52, no. 10, pp. 1215–1225, 2009.

[84] P. van Dommelen, J. K. Coffeng, H. P. van der Ploeg, A. J. van der Beek, C. R. Boot, and I. J. Hendriksen, “Objectively measured total and occupational sedentary time in three work settings,” *PLoS One*, vol. 11, no. 3, p. e0149951, 2016.

[85] V. Patel, A. J. Flisher, S. Hetrick, and P. McGorry, “Mental health of young people: a global public-health challenge,” *The Lancet*, vol. 369, no. 9569, pp. 1302–1313, 2007.

[86] M. Haller, C. Richter, P. Brandl, S. Gross, G. Schossleitner, A. Schrempf, H. Nii, M. Sugimoto, and M. Inami, “Finding the right way for interrupting people improving their sitting posture,” in *IFIP conference on human-computer interaction*. Springer, 2011, pp. 1–17.

[87] P. D. Adamczyk and B. P. Bailey, “If not now, when? the effects of interruption at different moments within task execution,” in *Proceedings of the SIGCHI conference on Human factors in computing systems*, 2004, pp. 271–278.

[88] F. R. Zijlstra, R. A. Roe, A. B. Leonora, and I. Krediet, “Temporal factors in mental work: Effects of interrupted activities,” *Journal of Occupational and Organizational Psychology*, vol. 72, no. 2, pp. 163–185, 1999.

[89] W. Buxton, “Integrating the periphery and context: A new model of telematics proceedings of graphics interface,” 1995.

[90] IALA. Threshold of perception), year = 2009, url = https://www.iala-aism.org/wiki/dictionary/index.php/Threshold$_{o}f_{p}erception,$.

[91] K. K. Elbert, H. B. Kroemer, and A. D. K. Hoffman, *Ergonomics: how to design for ease and efficiency*. Academic Press, 2018.

[92] S. Pheasant and M. Christine, “Haslegrave. 2016. bodyspace: Anthropometry, ergonomics and the design of work.”

[93] C. Harrison and A. K. Dey, "Lean and zoom: proximity-aware user interface and content magnification," in *Proceedings of the sigchi conference on human factors in computing systems*, 2008, pp. 507–510.

[94] J. Kim, N. H. Lee, B.-C. Bae, and J. D. Cho, "A feedback system for the prevention of forward head posture in sedentary work environments," in *Proceedings of the 2016 ACM Conference Companion Publication on Designing Interactive Systems*, 2016, pp. 161–164.

[95] OpenCv. OpenCV 3.3), year = 2015, url = https://opencv.org/opencv-3-3/,.

[96] S. Puttemans, E. Can, and T. Goedemé, "Improving open source face detection by combining an adapted cascade classification pipeline and active learning," *Proceedings of VISAPP 2017*, vol. 5, pp. 396–404, 2017.

[97] L. H. Kim, A. A. Leon, G. Sankararaman, B. M. Jones, G. Saha, A. Spyropolous, A. Motani, M. L. Mauriello, and P. E. Paredes, "The haunted desk: Exploring non-volitional behavior change with everyday robotics," in *Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction*, 2021, pp. 71–75.

[98] N. Owen, G. N. Healy, C. E. Matthews, and D. W. Dunstan, "Too much sitting: the population-health science of sedentary behavior," *Exercise and sport sciences reviews*, vol. 38, no. 3, p. 105, 2010.

[99] G. Healy, "Dunstan, dw," *Salmon, J. Cerin, E. Shaw, JE. Zimmet, PZ. Owen*, no. 2007, pp. 1384–1389.

[100] L. R. Renaud, M. A. Huysmans, H. P. Van der Ploeg, E. M. Speklé, and A. J. Van der Beek, "Long-term access to sit-stand workstations in a large office population: User profiles reveal differences in sitting time and perceptions," *International Journal of Environmental Research and Public Health*, vol. 15, no. 9, p. 2019, 2018.

[101] KONAMI. KONAMI), year = 2022, url = https://www.konami.com/en/,.

[102] NINTENDO. NINTENDO), year = 2022, url = https://www.nintendo.com/,.

[103] PlayStation.ca. PlayStation), year = 2022, url = http://www.playstation.ca/,.

[104] A. Grimes, V. Kantroo, and R. E. Grinter, "Let's play! mobile health games for adults," in *Proceedings of the 12th ACM international conference on Ubiquitous computing*, 2010, pp. 241–250.

[105] E. comission. Research and innovation, year = 2014, url = https://ec.europa.eu/info/research-and-innovation$_en$.

[106] S. Kierkegaard, "Cybercrime convention: narrowing the cultural and privacy gap?" *International Journal of Intercultural Information Management*, vol. 1, no. 1, pp. 17–32, 2007.

[107] I. Iancu and B. Iancu, "Elderly in the digital era. theoretical perspectives on assistive technologies," *Technologies*, vol. 5, no. 3, p. 60, 2017.

[108] S. H. Lee and Y. B. Kim, "Which type of social activities may reduce cognitive decline in the elderly?: a longitudinal population-based study," *BMC geriatrics*, vol. 16, no. 1, pp. 1–9, 2016.

[109] A. Thudt, U. Hinrichs, S. Huron, and S. Carpendale, "Self-reflection and personal physicalization construction," in *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, 2018, pp. 1–13.

[110] C. Fuentes, V. Herskovic, J. Heysen, and M. Tentori, "Towards a technology for caregivers' emotional expression and self-reflection," in *Ubiquitous Computing and Ambient Intelligence. Context-Awareness and Context-Driven Interaction*. Springer, 2013, pp. 143–150.

[111] T. G. L. Challenge. , year = , url = unesdoc.unesco.org/images/0016/001631/163170e.pdf.

[112] Wikipedia. Literacy in the United States, year = , url = https://en.wikipedia.org/wiki/Literacy$_in_the_United_States$.

[113] G. Friedland, W. Hürst, and L. Knipping, "Educational multimedia systems: the past, the present, and a glimpse into the future," in *Proceedings of the international workshop on Educational multimedia and multimedia education*, 2007, pp. 1–4.

[114] H. H. Ip and B. Kwong, "Smart ambience games for children with learning difficulties," in *International Conference on Technologies for E-Learning and Digital Entertainment*. Springer, 2006, pp. 484–493.

[115] F. Colace, M. De Santo, and N. Gagliardi, "Multimedia learning in advanced computer-based contexts:discovering trier'," in *2008 3rd International Conference on Information and Communication Technologies: From Theory to Applications*. IEEE, 2008, pp. 1–4.

[116] J. Frank. F. Furstenberg, S. P. Morgan, and P. D. Allison, "Paternal participation and children's well-being after marital dissolution," *American Sociological Review*, pp. 695–701, 1987.

[117] C. Pomalaza-Ráez and B. H. Groff, "Retention 101: Where robots go… students follow," *Journal of Engineering Education*, vol. 92, no. 1, pp. 85–90, 2003.

[118] G. J. Schafer, K. E. Green, I. D. Walker, and E. Lewis, "A networked suite of mixed-technology robotic artifacts for advancing literacy in children," in *Proceedings of the 11th International Conference on Interaction Design and Children*, 2012, pp. 168–171.

[119] J. Read and P. Markopoulos, "C15: Evaluating children's interactive technology. course notes," in *CHI Conference on Human Factors in Computing Systems*, 2011, pp. 7–12.

[120] Wikipedia. Sifteo Cubes), year = 2022, url = https://en.wikipedia.org/wiki/Sifteo$_Cubes$, .

[121] A. Karime, M. A. Hossain, A. El Saddik, and W. Gueaieb, "A multimedia-driven ambient edutainment system for the young children," in *Proceedings of the 2nd ACM international workshop on Story representation, mechanism and context*, 2008, pp. 57–64.