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Home-Based Activities for Children with Speech Sound Disorders: Requirements for a Tangible User Interface for Internet of Things Artefacts

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Abstract: This paper presents the state of the art regarding the use of tangible user interfaces for internet of artefacts (IoA) targeting health applications, with a focus on speech and language therapy and related areas, targeting home-based interventions, including data security and privacy issues. Results from a systematic literature review, focus group, and a nationwide questionnaire have been used to determine the system requirements for an artefact prototype to be developed. The aim of this study was to understand what is the usual practice of clinicians and to contribute to a better intervention or post-intervention approach for children with Speech Sound Disorders (SSD). The literature review revealed that some studies proposed technological solutions while others used a social approach and/or gamified activities. We could conclude that more research is needed and that a unified method or framework to address SSD intervention or post-intervention tools is lacking. Clinicians need more and better tools to be able to quantify and qualitatively assess the activities developed at home.

Keywords: tangible user interfaces; Internet of Things; children; Speech Sound Disorders; home environment; post intervention activities

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1. Introduction

Speech sound disorders (SSD) have tremendous implications in daily life and the effect that this pathology can cause later in life is well documented [1–4]. The typical approach to treatment by a Speech and Language Therapist (SLT) working on a one-to-one, face-to-face basis, is often not sufficient to cover a whole population [5]. The economic burden it places on families, and the limited support of children and families in larger countries [6] has led to the development of new models of service delivery based on telepractice [7] that have been shown to alleviate some of the problems. However, parents' involvement is necessary [8,9], particularly when an SLT prescribes activities. These activities are very important in continuing the intervention [10,11], but they pose challenges to all parties in the rehabilitation process (SLT, child, and parents). Tools or systems that support activities at home should allow the SLT to not only know if the activities were done, but also how much time was spent doing them and what were the answers to the different tasks, among other functionalities. Such tools should be easy to customise and use, with an emphasis in designing the interaction during the whole rehabilitation process, whilst retaining value, independently of age, dexterity, or perception of the users. The development of personal narratives based on (digital) storytelling, can improve language skills [12] and has proved its effectiveness in teaching and learning [13]. Storytelling is

capable of combining different elements, such as text, animation, and sound [14], that play a significant role in clinical intervention and also in terms of engagement.

Usually, the rehabilitation process for communication disorders in children takes place once a week in 40 to 50 min sessions [11]. Depending on the involvement of parents [8,15,16], follow-up activities at-home are given, in order to capitalise the time in-between sessions. These activities, however, are not easily assessed, supervised, or error-free. The importance of home activities in SSD intervention is well-established as well as that of the parents' involvement in the intervention process, be it at the clinic or at home [8,10,11,16–18].

This paper proposes an alternative to the traditional "pen and paper" approach for home activities [11], i.e., an approach focused on harnessing the latest 5G communication paradigm centred on the Internet of Things, that we will refer to as the "Internet of Artefacts" to deliver the use of a tangible user interface (TUI), based on a set of known activities or games, to deliver and log those activities. The use of this TUI would occur on the days between sessions, as Figure 1 depicts. Tangible user interfaces are able to merge the digital information world with the cognitive value [19] and affordances of a physical object.

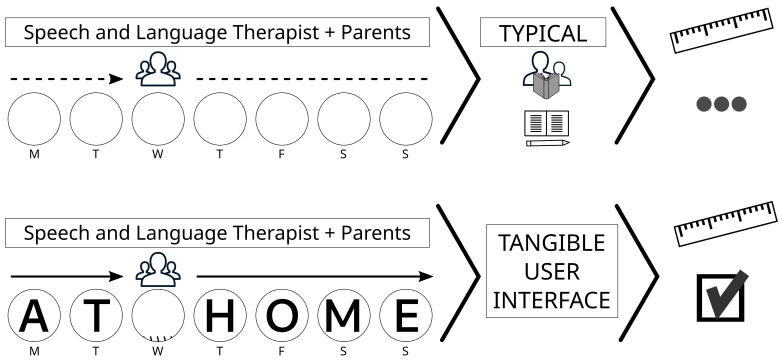

Figure 1. The typical schema (**top**) of a speech and language therapy session—once a week, unmonitored at-home activities versus (**bottom**) the proposed approach of using a TUI for monitored and engaging at-home activities. Adapted from [20].

1.1. Speech and Sound Disorders

Speech sound disorders take the form of gaps in children's speech sound systems that can cause difficulties in producing or understanding phonemes that are part of the inventory of typically developing children of their age [11,19,21]. Children with phonologically-based SSD present a number of phonological process-simplifications of the adult speech that typically occurs during language development. They can be seen as a systematic alteration or simplification that affects a class or sequence of sounds [11] in their speech [22]. Having difficulties with speech production may increase the risk of poor academic performance, due to the reliance on oral skills for developing various forms of literacy-related skills [17,23]. These children may develop reading and spelling difficulties that persist into adulthood, having well documented academic, social, and self-esteem issues [3]. The psychosocial factors researchers studied that might have a relation with SSD are age, gender, family background, and personality. The maturation or age of a child [24,25] has a known self-correction effect on speech sound acquisition and articulation skills, but many of these children need intervention since maturation alone will not resolve his/her problems [17].

The intervention plan and focus should be specifically tailored for each child and evolve and adapt during the intervention process [18]. Every child is unique, and it is known that more sessions per week can have a larger impact and more lasting effects on children with SSD [26]. A conceptual model based on a TUI artefact may provide a viable solution to capitalise intervention "downtime" and may act as a catalyst for at-home activities [10]. Current recommendations include a Family-Centred Prac-

tice, which promotes not only the parents' involvement in the sessions and in homework activities, but also in planning a session (setting goals) [9,18]. The continuation of the intervention at home, using activities planned by the SLT, allows the family to explore and learn in a natural and friendly ecosystem, adapting the activities to functional contexts [11]. It can be seen as a mixture between an indirect intervention and a direct intervention approach, i.e., the SLT plans the intervention with the involvement of parents, who will be the "actors" of the planned intervention, having been "trained" previously by the SLT.

1.2. The Home Environment

A home encompasses both a place of residence (domicile) and a social unit formed by a family living together [27], i.e., a home is a physical object with a social unit at its core. Despite the abundance of technology and its usefulness, not all of it is calming or pleasant; and thus, fails to integrate well with the sense of comfort and of the self in a home environment [28]. Technology and everyday routine are so blended together that the notion of what came first, the routine that used technology or the technology that created a routine, starts to fade [29]. This process of appropriation of technology has unwritten rules, and sometimes exploits technology in more diverse ways than envisioned by the technology's manufacturers [30]. Nowadays, use of new technologies at home has steadily increased and shapes daily routines, and drives quality of life [31]. Interestingly, the relation between home and technology appears to be coming full circle. In a home full of technology [32], technological appliances are becoming "invisible" (in Mark Weiser's ubiquitous sense) and a certain sense of insecurity and dislike towards the "invasion of the home by outside forces" that remotely access and control technology exists and may hamper technology adoption [33–37].

Despite the perceived importance of the home environment, there is still a lack of studies that connect home and home life with health, behaviour, and social skills [38]. There is also the need to study the home environment outside of controlled conditions, i.e., in a laboratory [39], which may lead to the need to make use of ethnography and non-disruptive instruments. Ethnography is a form of qualitative research [12], originating from cultural and social anthropology studies [40], where it is seen as both a method, a theory, and a style of writing [41] that seeks to study societies and cultures through examination of the complexity of human, interpersonal, social, and cultural aspects [42,43]. When using an ethnographic participant-observation approach to study a household, informal conversations, interviews (in-person or remote), focus groups, surveys, cultural probes, and artefact analysis, are all used to collect data [39,40].

1.3. Tangible User Interfaces

Tangible user interfaces (TUI) have moved us away from the typical and generic combination of screen, mouse, and keyboard interaction, transforming the world itself into an interface [44]. This is achieved through augmentation of real-world objects and environments with digital information [44]. Tangible Interfaces can be defined as those that support the user's direct interaction with the digital world by use of real-world physical objects or tools [45]. They use physical forms designed and improved over the millennia to fit a specific task [46], thus facilitating the user's legibility and direct manipulation through peripheral senses (e.g., touch or vision) due to its physical embodiment [44,46,47].

Several authors [45,48–54] have shown that TUI can support learning and development processes [50,55], because young children do not grasp menu structures, layered interfaces, or icons. This is especially true when learning a language due to its increasing symbolisation semiotics—(the word dog has the same meaning/relation to an image or drawing or actual dog). Children's natural interaction style is exploratory and multi-sensory [56]. Furthermore, TUI require less interpretation, allowing for a more flexible interaction and collaborative use, permitting sensory experiences, and are persistent [47,56]. Some authors suggest that TUI should be reactive, in order to solve inconsisten-

cies and provide additional feedback [57,58] or in order to be easier to use by children with disabilities [56]. This would allow for an interface that communicates to the user changes in the system by re-arranging the user interface or even adjusting the display to reflect changing information or user interaction [57,58].

However, the TUI approach may not be suited for older children. Both Bowen and Cupples [8], while developing an intervention approach for SSD, and Sapounidis and Demetriadis [59], in a comparison between TUI and graphical user interfaces for programming robots, concluded that older children preferred other methods of interaction.

1.4. Internet of Things

Weiser's concept of computers everywhere (ubiquitous computing) that would make computers disappear from the user's conscious thought similar to how we today perceive electricity, a commodity that is always present [60] is perhaps closer to reality with the advent of the internet of things (IoT). For a device to be an IoT object, it needs to [61] physically exist and possess physical features, be able to communicate, be discoverable; accept and respond to incoming messages; have a unique identifier; have one name (human readable); have an address (machine readable); have basic computing capabilities; be able to sense physical phenomena or actuate (causing effects) on the physical world. Internet of things has still some challenges to solve, such as privacy, participatory sensing, data analytics, geographic information, and computation stack (cloud, edge, and fog computing [62]). Wireless Sensors Network challenges include architecture, energy efficiency, security protocols, and quality of service [63]. Some authors [64–67] and the European Union via the General Data Protection Regulation [68] and the European Standards [69] have already presented some solutions to the coming challenges of security and privacy in an increasingly interconnected world and home.

When discussing security and privacy concerns in IoT devices it should be noted that this is a growing field, with Cisco estimating that by 2023 it may reach 29.3 billion devices connected to the Internet and from these half (around 14.7 billion) will be connections from machine to machine (the IoT devices) with the larger share of these machine to machine (M2M) connections being from connected home applications [70]. This means that challenges will undoubtedly rise in the coming years but also that they are transversal to our society (production, services, and the private sphere) with the latter offering the possibility of sensitive data collection that, when combined with further data and M2M communications, can lead to potential security and privacy risks and unlawful use of data [71,72].

1.5. Rational and Research Questions

Previous work [20] by the authors established the feasibility of tangible interfaces and their ability to transpose common activities used by SLTs when interacting with children with SSD. Tangibles were more engaging and SLTs expressed their desire to have better tools to intervene and assess, when children are at-home.

This paper thus explores the potential of Tangible Media or Internet of Things Artefacts being used in the context of an at-home intervention in children with SSD. The previous sections provided the necessary basis to understand both the relevance of this research and the technological approach. The research areas to address include the potential of Tangible Media as the basis of a semi-autonomous intervention for SSD in an at-home environment; and the importance of activities that take place at-home and with the parent's help, and how can those activities be monitored, reset, made playful, and assist in the SLT intervention.

1.6. Structure of the Paper

This paper includes a Materials and Methods section organised into the following subsections: Literature review—initial search query and keywords; focus group; questionnaire; ethics committee authorisation. Then, the results are presented in a section consisting

of a systematic literature review, focus group, and questionnaire. These results are then discussed in the same order, and conclusions and future work are presented in the last section of the paper.

2. Materials and Methods

A systematic literature review, focus group, and a nationwide questionnaire have been used to address the research questions.

2.1. Literature Review—Initial Search Query and Keywords

In order to ascertain the state of the art pertaining TUI for IoT artefacts as tools at-home, post SLT intervention, with children with SSD a systematic review was done, using the PRISMA methodology [73], based on queries in the Scopus [74], Web of Science [75], and PubMed [76] databases.

While both TUI and IoT have several real world applications, such as IoT's Smart Cities [77,78], industry [79,80], or health and rehabilitation services [81–83] (to name a few), it would not be viable to describe them all in the current paper. Instead, we have opted to focus our attention on the previously mentioned subjects, keywords, and applications.

In Scopus, the advanced search query was used with the following keywords, Boolean operators, and time limiter,

> TITLE-ABS-KEY((“tangible user interfaces”) OR (“internet of things”) OR (“smart object”) OR (toy) or (game)) AND child* AND speech AND language AND disorders AND PUBYEAR > 2010

A variation of this query was used in Web of Science,

> AK=(((“tangible user interfaces”) OR (“internet of things”) OR (“smart object”) OR (toy) or (game)) AND (child*) AND (speech) AND (language) AND (disorders))dimension of a suitable FG

The PubMed search was conducted with the following,

> ((“tangible user interfaces”) OR (“internet of things”) OR (“smart object”) OR (toy) or (game)) AND child* AND speech AND language AND disorders Filters: in the last 10 years

In these searches, the concept of the technology was broadened, including TUI, IoT, smart toys, games, and toys in general, while keeping the target group of children and speech and language disorders (each as its own independent keyword), as the motivations behind the study. The rationale was to steer the search in such a way that information about methodology, user requirements, frameworks, pitfalls, and a sense of the latest research trends in the subject matter could be teased out.

2.2. Focus Group

The use of focus groups (FGs) is extensively documented in the literature, ranging from academic papers to non-academic, market-driven literature. Focus groups can be understood as a group interview in a low-pressure and non-threatening environment [84,85]. A Focus Group (FG) has very specific characteristics and procedures to adopt, including the use of a moderator to guide the group based on pre-prepared material [84,86–91].

Interactions between participants that share a set of common traits related to the study in question allow for different viewpoints on the same subject without the pressure to achieve any sort of consensus [84,92]. Thus, FGs allow for information to be gathered that would otherwise not be possible in an in-depth one-to-one interview [89], namely, a less politically correct opinion or critique, instead of the pressure to give the interviewer the socially expected answer in an individual interview [92]. The number of FG participants varies depending on author or field of study, but there is a consensus within the research community that between 5 to 10 participants seems to be sufficient [84,88,89,93].

However, these numbers are *per session*, with all authors, independently of the field, saying that more than one FG should be held and some even providing ways (ideal percentage) to calculate the total number of participants needed to achieve a representative sample that can yield the data required [85].

The results presented in this paper are those of a single FG session with SLTs and human-computer interaction (HCI) specialists that shared a common objective, namely, treating or developing solutions for children. The FG materials as well as the questionnaire were reviewed in a one-to-one informal in-depth interview with a senior SLT specialist that graciously discussed them with the first author of this paper, beforehand. This allowed for an unbiased and expert set of eyes to check both tools in regard to content, structure and detail [94].

The FG consisted of 5 specialists, two moderators and a person that was taking notes and pictures. The session ran for approximately 2 h and 30 min, was audio recorded and a transcript of the FG was later produced and sent to all present for feedback. The participants were invited and briefed by email prior to the FG session, and signed an informed consent regarding the capture of audio, images, and why and how that data would be used.

The FG was divided into three phases, namely, (i) ramping-up period that also served to present the idea and why participants were invited, which ran for approximately 30 min; (ii) brainstorming and interactive session on the notion of a possible artefact that could deliver at-home activities for children with SSD, and what they, as SLTs and HCI specialists, felt was needed or could benefit the children or negatively impact them, which ran for approximately 50 min; and (iii) content validate the questionnaire described below, which ran for approximately 50 min. A coffee break occurred between the second and third phases and lasted around 20 min.

The second phase consisted of a set of activities and roughly followed a structure that allowed the generation of ideas and their reduction until one meaningful approach was determined [95]. Several ideas and concepts were generated in a brainstorm activity, using sticky notes of different colours to symbolise, for example, danger (red), requirements (green), and so on. After that initial moment, the moderator, using a whiteboard, asked the participants to choose the most promising idea of an activity and develop that idea, incorporating or rejecting concepts and requirements identified in the sticky notes. When the activity was drawn on the whiteboard, new ideas were discussed and adapted, if agreed upon.

In the third phase, the gathered expertise of the FG participants was used to better inform the further development and refinement of the questionnaire tool, as advised in [89]. Each of the participants received a copy of the proposed questionnaire, analysed it, and ranked the questions regarding validity, structure, and sequencing [94].

2.3. Questionnaire

The questionnaire was divided into 5 parts and had a total of 42 questions. The first part served a twofold purpose, i.e., to inform participants that the questionnaire was anonymous (except for necessary metadata in order to save the questionnaire and allow it to be finished later if needed) and that the data would be destroyed after the study is completed; and to define a simple scenario (akin to a real clinical case) to make the respondents think and answer with a certain mindset. The second part of the questionnaire (with six questions) included questions regarding years of practice and geographical area. Participants were also asked if they had the habit of sending tasks to be completed at-home with the family. The third part (with 15 questions) was all about how the family was involved (or not) in the intervention. If the participant did not choose to involve the family, he or she would be asked to explain why not and would be taken to the final part (the fifth part) of the questionnaire. For those participants that answered yes to involving the family a fourth part of the questionnaire, with 11 questions, was ensued. The goal here, was to understand how the participant sought to continue the session post-intervention,

and how he or she accessed or monitored that continuation. Finally, the fifth part was designed to understand if the participants were aware of new forms of intervention (such as teletherapy), how open they were to try out new tools, and how they thought a new tool should function and what it should comprise.

The questionnaire's dissemination strategy was two pronged, consisting of a snowball approach, based on the research team's contacts in academia and with practising SLTs; and contacts with two national SLT associations and requests to promote the questionnaire.

2.4. Ethics Committee Authorisation

Ethical permission was obtained from an independent ethics committee (Conselho de Ética e Deontologia da Universidade de Aveiro, Parecer nº: 38-CED/2019) and informed consent was collected from all participants prior to data collection. The study was also certified by University of Aveiro's Data Protection Officer on the 27 January 2022.

3. Results

3.1. Systematic Literature Review

The results of the search in Scopus [74], Web of Science [75], and PubMed [76] databases, are summarised in Figure 2, using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (drawn using an online flow diagram creator [96]).

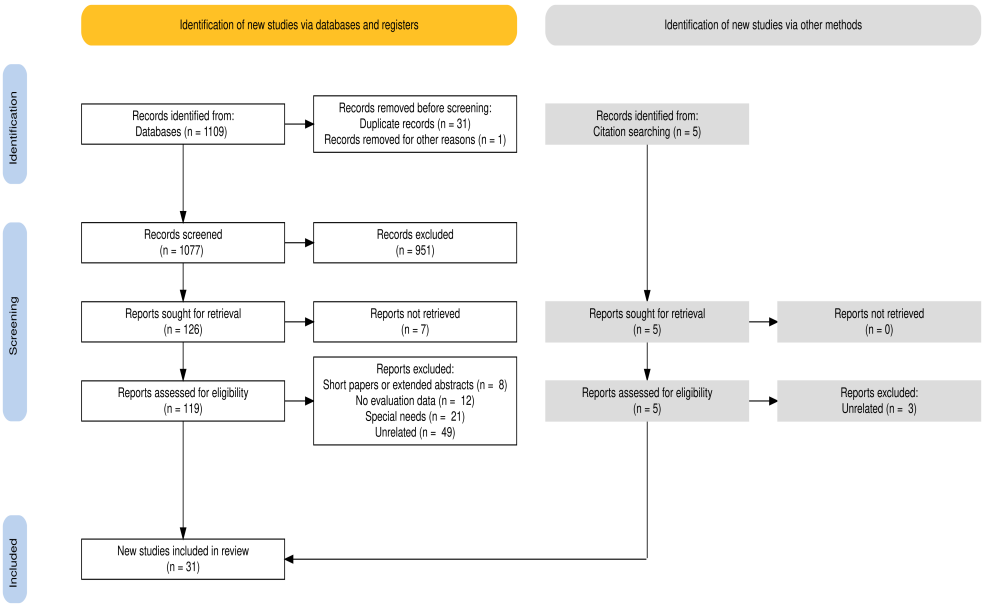

Figure 2. PRISMA flow diagram.

We found 1109 records in 3 databases (Scopus with 1081 results, Web of Science with 2 results, and PubMed with 26 results) as well as 4 other records from citations or prior unrelated searches. After removing 31 duplicate records and 1 record removed for other reasons, 1077 results were screened by title and abstract with 951 being excluded. Seven of the remaining 126 records could not be retrieved, and 90 were excluded due to being short papers, extended abstracts or workshops reports, that either had no evaluation data, a focus in unrelated (to SSD) areas (e.g., Cerebral Palsy, Autism, Aphasia, Deafness, Stuttering, or Visual Impairment), or addressed unrelated research goals, such as referencing simple toys, discussing speech and language therapy that was not technology-based. Three records from other sources (the grey boxes in Figure 2) were excluded for not being related to the present study, and two records were added to the review.

Perhaps one of the most interesting results from the initial queries on scientific databases is the lack of studies in the area of this paper, evidencing the need for further

research, and to create a common framework that can serve as a bridge for a transdisciplinary approach by an interdisciplinary research team [97]. This is especially urgent in this area due to the very negative impact it can have on the present and future life of children with SSD.

The *VOSviewer version 1.6.18* [98], a software tool developed to visualise bibliometric networks, was used in conjunction with Scopus' analytical tool to further investigate the data available from the relevant studies included in the literature review. Subjects ranged from Computer Science to Neuroscience, a diversity that produces an abundance of designations for the same area (shown in Figure 3), created by the authors or automatically generated by the publishers. Figure 3 was generated by Scopus analytical tool, based on the bibliography that were retrieved from the initial search of the literature review.

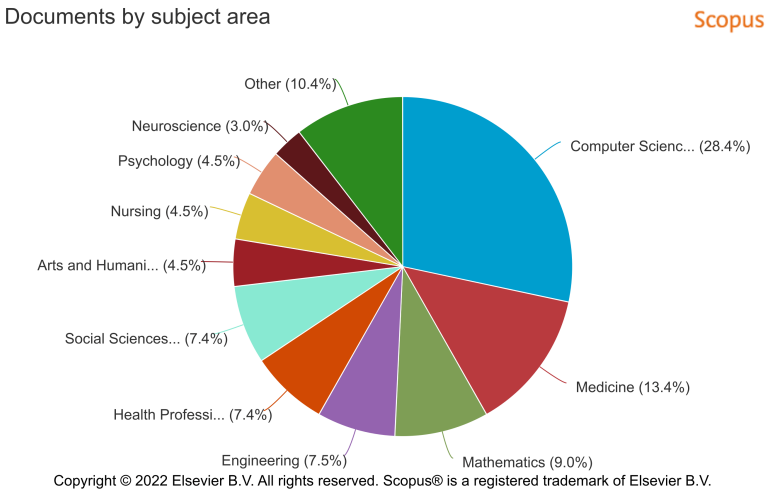

Figure 3. Percentage of documents by subject area.

The variety and richness of the keywords and different approaches interconnected to or with TUI and IoT devices, with speech disorders and speech and language therapy is plain to see in Figure 4. The co-occurrence of keywords shows not only the above-chance frequency in which two terms occur in different texts, but also the potential relations between those terms and other concepts [99]. The analysis in Figure 4 highlights possible areas for cooperation overlaps with other technologies or fields of research and current trends.

Figure 5 shows the results of an analysis based on title and abstract fields only, while ignoring copyright statements and other common labels. There is a full count of the occurrences of a term, with a minimum of five occurrences in order to qualify for the analysis, with 60% of those terms selected (based on a relevance score). This resulted in 38 terms that were then manually refined to delete terms such as minute, research, paper, year, type. The end result shows that there is not a single disconnected term. Even those that were further away from the centre (three or four nodes away), and appeared less prominent, were connected.

When addressing the challenge of providing an accountable at-home, post-session continuation of speech and language therapy, through use of exercises, games or toys, and supported by parents, this literature review provides a fresh perspective on what has been done and what seem to be the most recent trends in research.

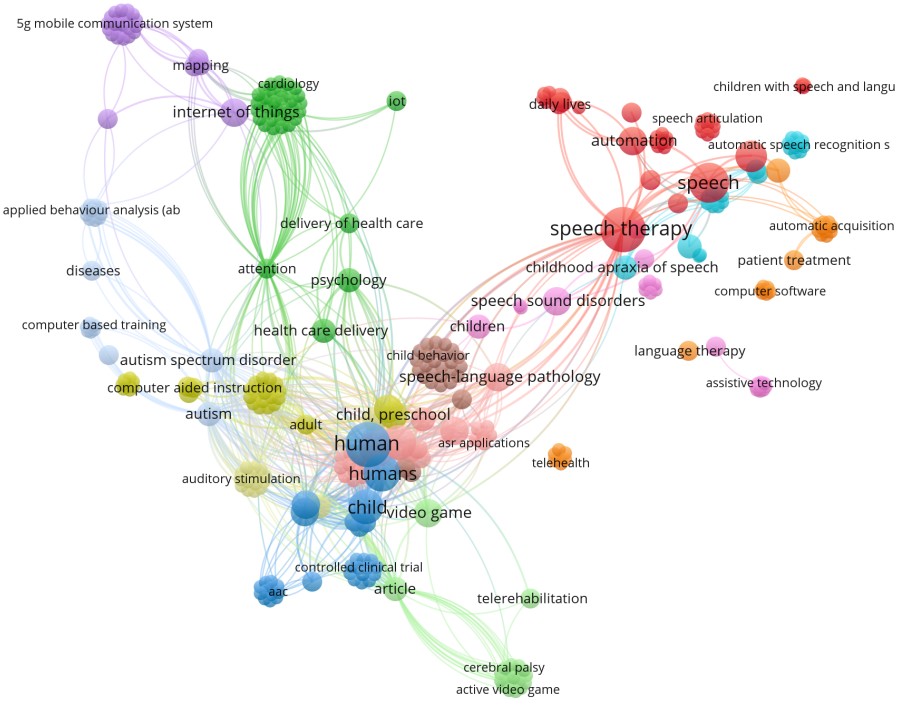

Figure 4. Co-occurrence of automatically generated keywords in selected bibliography for literature review.

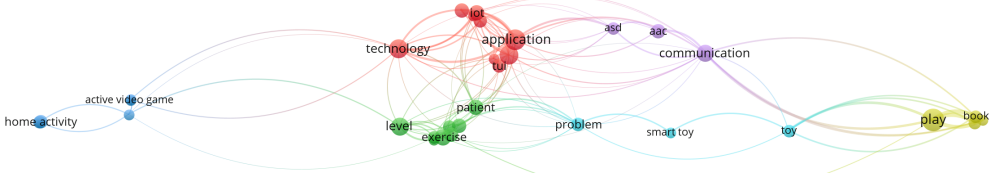

Figure 5. Network after analysis of the papers included in the literature review.

The closest literature [19,100,101] to our own research goals use a technology-based intervention (TUI [19], tablet, or mobile app [100] or a web system [101]) to support speech and language therapists (SLTs), parents, kindergarten teachers, and assistants [19] when addressing the needs of children with SSD. However, one of the studies [19] did not involve the parents, and another study [101] was only based on SLTs' and caregivers' input. Two papers [100,101] reported the mechanism used to assess children's speech and language, and provided a report to the SLTs, based on an automated speech analysis system, which was also at the heart of other studies [100–105]. Bono et al. [106] engaged parents as co-players, while other authors [100,102–104] simply implemented the system with an at-a-distance control or report for SLTs and children (parents were not included). What many of these approaches seem to ignore is the need for social interaction. The control mechanism of Santos et al. [19] was designed for SLTs, parents, kindergarten teachers, and assistants. This was by design, in order to promote social interaction, a key factor in SSD intervention [107,108]. Parnandi et al. [100] and Desolda et al. [101] both identify the risk of boredom and repetitiveness and address it with the ability to customise exercises and backgrounds according to the user's preferences [101] or by acknowledging the need to constantly evolve or update the app [100]. Future work directions indicated by Desolda et al. [101] are evolving towards the use of IoTs.

The study by Rincón et al. [109] addresses the treatment of language disorders, with the possibility of customisation of the material to suit individually each child. However, the authors' goal was the creation of a tool (a video game) with specific objectives. This tool or software product line was able to reuse its assets and create up to 90 different mini-games

or activities, for children between 4 and 6 years of age. At the same time, a web portal was also created, allowing customisation (for children and SLTs) and the production of mini-games.

Some tools [100,102,105,107] used rewards to increase the amount of time spent by children playing and to potentiate enjoyment and the desire to replay. Parnandi et al. [100] mentioned rewards as an idea to explore and simply as another extra to keep the interest. Ronimus et al. [107] analysed time spent playing and concluded that after an initial increase in time spent and interest, it decreased in subsequent plays to typical levels. Also, when comparing total time values with those from a control group [107], there was not a significant difference. Since rewards have been shown to have a limited impact, various additional strategies should be used to develop a more engaging tool, including opportunities for choice and to have it impact the game world; clear long-term goals; feedback regarding the player's progress and skill level; and collaboration with other players such as parents. It should be noted that authors such as Ahmed et al. [102] simply stated that children enjoyed games with rewards, challenges, and multiple difficulty levels. One study [107] tested a single game over eight weeks to "mimic" an intervention duration, while another study [102] encompassed five different games and the purpose was more on testing preferred control and game types. The authors [102] pose the question of how players would react to longer periods of game use. The type of reward may also play a part [105], where the targeted users, probably due to age (adults with speech impairments), preferred physical real-world rewards or accolades.

Some authors tested [19,108,110,111] or are in the process of testing [101] the use of TUI, IoT devices, or a mix of both, with children. At least one study [112] in this literature review is adamantly against electronic-only games for children with speech, language, and communication needs, stating that exposure to communicative interaction between parents and child is of utmost importance. Since TUI can be seen as a mixture of physical properties augmented by digital characteristics [108], they might fit this role, as one study [110] implies, while cautioning about some design guidelines, such as a the correct TUI size to facilitate its manipulation by small children, the need to reduce unnecessary body movement, or the care needed when designing negative feedback to avoid misapprehensions. Medical IoT devices [81] have mostly been implemented at home, allowing a more cost-effective approach to therapy and patient engagement. Hasan et al. [111] detailed the approach in terms of tool development with a hardware part and a mobile application, and how they enabled different activities and recorded data, to show the player's progress. Ekberg et al. [113] question the value of physical toys, how they are used by SLTs during face-to-face intervention, and in telehealth. Physical toys are used by SLTs to promote certain activities or work on skills useful beyond therapy [113], but a child's engagement with those toys, in a one to one session, is dependent on conditions or rules imposed by the SLT. Those conditions are difficult, if not impossible, to enforce at distance [113] so Ekberg et al. [113] concluded that one should not assume that objects used in physical interventions can retain the same value or importance in a remote intervention. Lorusso et al. [108] use both TUI and IoT as well as other technologies to provide an integrated system that can promote positive social interaction in children, and Buono et al. [114] further expanded on both the use of home environment and the need to develop tailored approaches. Buono's et al. [106] approach was to empower parents and SLTs to be able to create rules for existing smart objects in the house, through the use of a visual interaction paradigm, in order to assist in the intervention as in [115]. Tangentially related to IoT and involving the entire home environment into the speech and language therapy process has been tested by Cassano et al. [115]. They [115] proposed the use of a smart home environment as an active supporter and emotional generator for children with SSD. In this study [115], SLTs used software to assess the existing devices at a house and to plan/assist an intervention. The house would control other smart objects, i.e., the smart TV, and through that control would indicate therapy time, use areas of the house to engage in

therapy, or improve that engagement by tuning the smart TV to a specific channel to act as reward.

The use of video games in intervention is addressed by several authors. While video game use, be it in the form of serious games [103,105,106,109,116], as a gamified activity [19,114,117], or simply as games that serve to entertain and engage [118], and then be used as a pop-up activity [104,119], can also be linked to TUI or IoT use, the articles revised here are about the game itself (its creation, value or applicability) and not the interface or interconnection with various devices. Bono et al. [106] starting point was an existing framework (The Early Start Denver model) for the treatment of children with autism, from which 11 games were derived. The platform created was deemed feasible for home-based intervention as well as clinical child-therapist intervention. The platform has the ability to verify a child's initial weak and strong points, thus ensuring an adequate intervention by choosing the appropriate games and keeping track and monitoring the child's progress through time [106]. Bono et al. [106] discussed the need of an evaluation that followed a specific methodology, the difficulties some parents had with the platform, and the impact gender had on the use of the platform. According to Hair et al. [104], by limiting the amount of daily gameplay, children would be more eager to play and therapy time could be extended. Some studies [100,101,104], concluded that personalisation or customisation of in-game assets were a popular and engaging aspect of gameplay. Zaki et al. [116] discussed 86 design guidelines, divided in 15 categories ranging from identification (of the child) with the game to cognitive development, but the opinions and inputs of children in the user testing process were still not considered.

A few studies [103,117,120] acknowledge the lack of speech and language therapy resources in specific languages. While Zajc et al. [120] query the SLTs regarding their perception of tablet use in intervention, in Gacnik et al. [117], the authors move on to discuss the awareness of SLTs regarding the use and perceived advantages of a mobile gamified application and the limited usefulness of a foreign language application use. The study addresses the necessary steps in order to create an application suited for SLT use and its evaluation.

At least one study in this literature review [108] identifies storytelling as an important factor in eliciting emotional involvement from the users facilitating their adherence to on-task behaviours and reducing defiance behaviours. One paper [121] focused on the use of a design-based research approach to inform the stakeholders involved in developing a game. Du et al. [121] further posit that research should include an ethnographic approach regarding technology use in intervention between children and SLTs, and make use of child-centred participatory design workshops that also involves SLTs [121–123]. Reichle et al. [122] clearly state that anyone with communication needs deserves individualised and appropriate support and that those people have the right to be involved in all aspects of research, development, and intervention. Boster et al. [123] actually implement the concept, and after a series of focus groups with stakeholders, identify features that parents and SLTs would like to see further explored in applications for children.

Of some interest to the home environment and the continuation, at home, of SSD intervention related activities, is how much time a child or parents assign for a particular task [124]. A study [124] reports that parents of children with speech impairments promote more activities inside the home rather than outdoors, but there was not a significant difference between a control group and children with speech impairments when it comes to time spent with literacy related activities.

The available technologies as well as the opportunities for development and the most used security methods in IoT in medicine have been previously reported [125]. Security threats in IOT, especially in medicine, have also been categorised, together with typical countermeasures [126].

Besides the mentioned use of automated speech recognition tools, other identifiable trends are the use of artificial intelligence (AI), be it either to propose new approaches to clinical assessment [101], propose an intervention and report, the use of

virtual reality or augmented reality [108,118], and the use of speech-driven [105] or speech-controlled [102,104,119] activities or games.

An attempt to introduce a technologically mediated intervention for children with SSD needs to be adapted for everyday use. That adaptation should be evidence-based, taking into account empirical recommendations and workplace limitations to produce the desired outcomes in a real life scenario [11,127].

3.2. Focus Group

From the analysis of the focus group transcript several activity and technical requirements and perceived pitfalls, be they technical or with regard to intervention or social interaction, transpired. Those requirements were sorted into three groups, ranked by priority, from high to low. The rationale behind these choices was related with available time, materials, and know-how constraints. The high priority requirements are presented in Table 1.

Table 1. High priority requirements as well as identified pitfalls.

High Priority	Activity Requirements	Immersive | Versatile | Intuitive-does not need digital literacy | Engaging—for children, caretakers and SLT's | Allows interaction between family members or other children with the activity—Social use and impact | Needs to be perceived as a continuation of the therapy | Parents need to understand the objective of the activity | Needs storytelling-associate the challenges to scenarios or actions or story | Playful—activity must/should be a moment of fun between child and caretakers.
	Technical Requirements	Data encryption and other security approaches—GDPR | Feedback-haptic, visual, sound | Allow log registry—number and type of errors, time spent, reaction time and access to said log by the SLT's | Allow remote resetting of game/activities by the SLT's and should inform the parents of said changes.
	Possible Pitfalls	Has to prove it is a beneficial technology | Should not disrupt social life | Should not contribute to the feeling of wasted time.

In Table 2 the medium priority requirements are addressed. The rationale behind the ranking of these requirements is that while some can be understood as very beneficial, they are not essential to the creation of a prototype or product.

Table 2. Medium priority requirements as well as identified pitfalls.

Medium Priority	Activity Requirements	Preferably should captivate/allow the entire family to participate | Should have multiple scenarios or just a very good one | Allow collaborative learning but respecting each one's pace according to the flux theory by Mihaly Csikszentmihalyi by adapting difficulty levels, questions and time to complete an action | Activity should be universal—not designed for one specific user or one specific speech disorder | Improve quality of time spent.
	Technical Requirements	Make use of virtual environments when developing to avoid package versions mismatch.
	Possible Pitfalls	May not be appropriate for all types of intervention (may work in perception/decision and meta-analysis but not in speech production UNLESS it is mediated by an adult).

The low priority requirements are presented in Table 3. The rationale regarding the classification of these requirements is that they are valid and would turn the prototype into a more active tool for mediated, at-a-distance, speech and language therapy.

Table 3. Low priority requirements as well as identified pitfalls.

Low Priority	Activity Requirements	May be played alone | Allow multiple explorations or uses | Customizable | Allow multiple users | Allow avatar creation | Should have different levels and produce clues, if needed | Allow to play with or against a remote user—another child or the SLT.
	Technical Requirements	None disclosed.
	Possible Pitfalls	Costly.

3.3. Questionnaire

A total of 33 SLTs responded in full to the questionnaire, with 81 SLTs partially participating. Only the full participation was taken into account. This may have been due to it being perceived as time consuming, as well as the approach used, i.e., participants had to justify each answer given.

Regarding SLTs' years of practice, most of them (n = 9) had "more than 10 but less than 15" years, 8 SLTs had "more than 15" years of experience, and a further 8 SLTs had been practising for "more than 1 less than 5" years. Interestingly, the group with the lowest number of participants was the group with the least time in the profession. Portuguese SLTs' main areas of work were also analysed according to ASHA's employment settings [128]. Figure 6, shows SLTs' answers, plotted as a tree map, where the colours are random, but the area size and the numbers at the top right represent the amount of answers given, per area. The answers were also clustered into two main areas (Education and Health), representing 21 SLTs that worked in the private sector, 8 were employed by charities and only 6 were public servants. While the Health area is marginally the principal area of employment, with 34 answers, against 33 answers in Education it must be perfectly clear that these values exist due to an SLT being able to have multiple jobs, in different areas, and the answer was open enough to allow exactly this. Private practice was the most common area of work (24 SLTs), with Middle School coming close (18 SLTs).

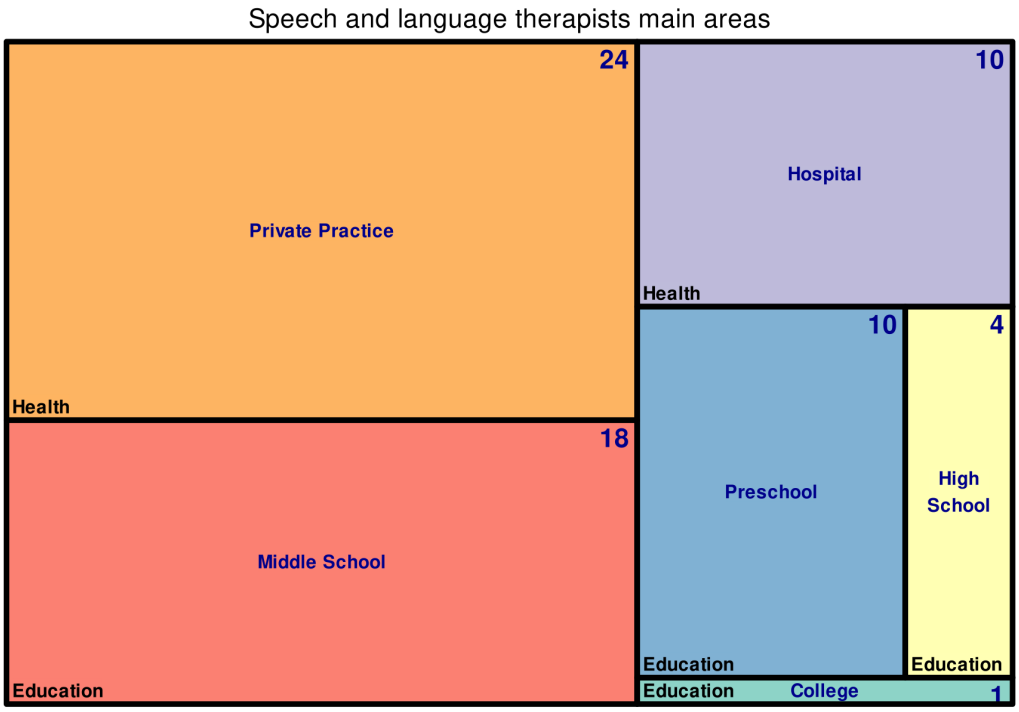

Figure 6. The main areas where these professionals carry out their activities.

In Figure 7, the tools and strategies to assign work and communicate with families are plotted after coding the answers and reducing them to a single word that encapsulates their meaning or the main idea. Two important facts to keep in mind in Figure 7 are that from the 33 respondents, 27 answered this question, since it was mandatory for those that in a previous question stated that they did not have direct contact with the family. The other fact is that not a single SLT used just one tool or one way to communicate, which makes sense in today's society, where smartphones and social networks are everywhere all the time. The most used tools were the telephone and diary, both with a certain degree of familiarity while being practical.

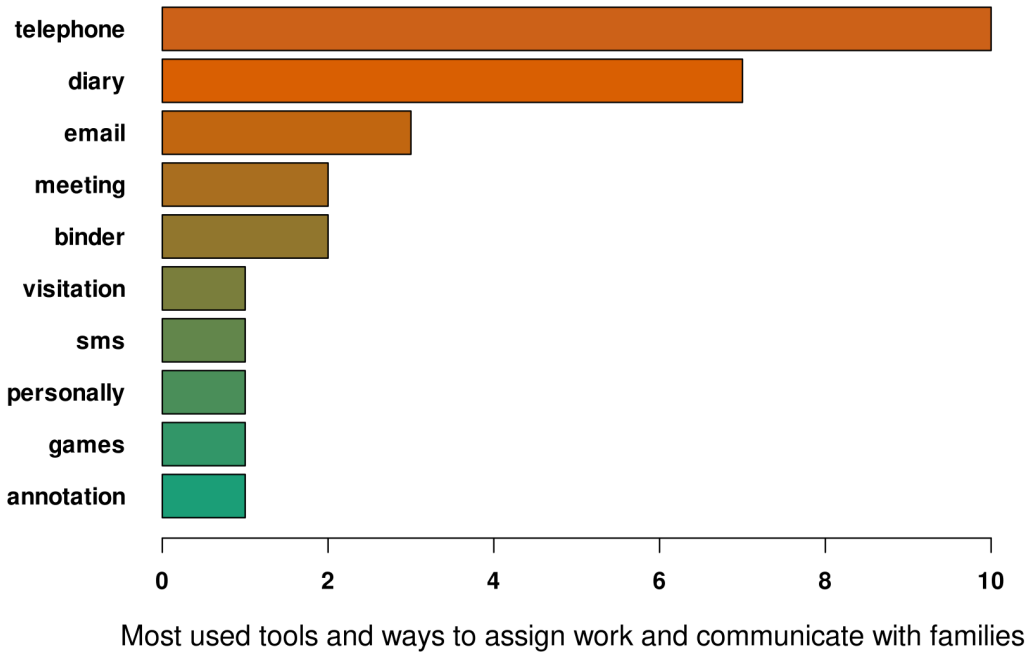

Figure 7. The tools and strategies SLTs use to work with families.

Speech and language therapists were also asked if they used home activities and, if not, why. From the 33 participants, 14 sent activities home, 11 did not send activities, and 8 did not answer. Most SLTs did not send any particular activity, such as reading, drawing or similar, but instead asked and gave instructions to the parents to try to turn the common house routines into activities and moments to stimulate the child's speech. Two SLTs highlighted lack of interest from the parents, who assume that the child is already being treated by an SLT and as such they do not need to do anything or support any extra assignments

One of the goals of the questionnaire was to assess the family involvement in the therapy process. Not only if the family was invited to participate, but also how they reacted. Figure 8 has three different charts that visually tell us the story of family involvement in the session promoted by the SLTs.

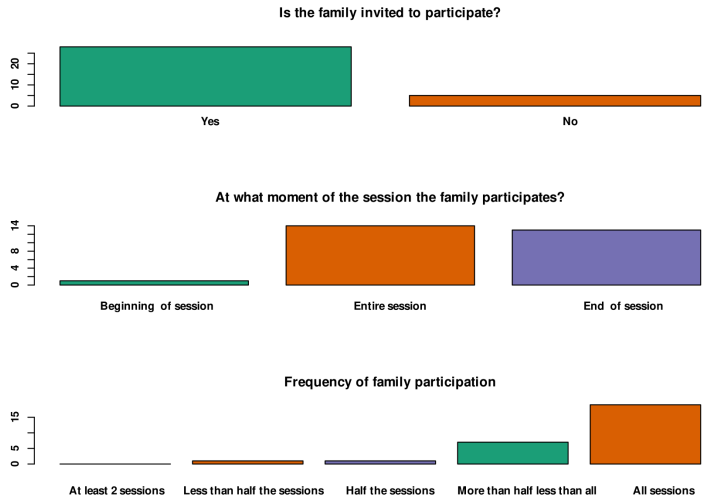

Figure 8. The story of family involvement in the therapy sessions.

Figure 8 shows that most families were invited to participate, that half of those that chose to participate did so over the entire session and the other half at the end of the sessions. Most of the parents were involved in more than half of the sessions. It should be noted that evidence from further informal interviews with SLTs show that the participation at the beginning and end of the session is, many times, reduced to the brief moments where the parent drops off or picks up the child from where the therapy session took place, lasting a couple of minutes at most. This is reinforced by the analysis of the answers used to generate Figure 8. While some SLTs say that they try to ask families to participate in the entire session, many also say that they include the family in the last minutes of the session or that they are "included" in the session by passing feedback to them.

Speech and language therapists then rated the family participation during sessions using a 5-point Likert scale, that ranged from non-participative to strongly participative. Results showed that families were mostly perceived as being Participative (12 answers) and Strongly Participative (3 answers), but some were also seen as Neutral (4 answers). However, when questioned, about how committed the families were, SLTs revealed that it was quite variable in time, with the child's progress acting as a positive element in terms of participation. The strategies used to monitor and support the families were mostly based on direct contact, as shown in Figure 9.

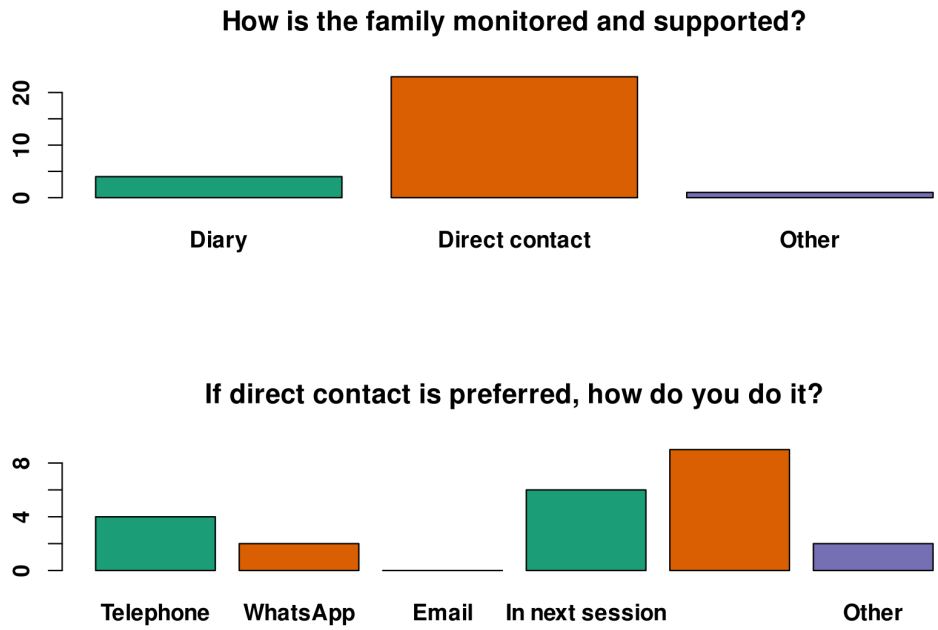

Figure 9. Monitoring and supporting the family.

The questionnaire also assessed the continuation of the intervention therapy process, at-home. This part was answered by 28 respondents only, because the remaining 5 had previously answered that they did not involve the family. The answer to the question "Do you usually send activities home, to be done by the child with support from parents?" had a majority of SLTs answering Yes, with only four negative responses. This shows the importance of not only the continuation of the session at the clinic or school, but also of the parents' involvement. When questioned about their negative answer, four SLTs revealed that they preferred to send or exchange with the family sets of instructions in order to adapt everyday life into speech and language exercises, instead of sending worksheets. The 24 positive respondents were further questioned regarding the types of exercises they used. Every SLT used more than one exercise type, so the answers were coded until a single word could describe their meaning, an idea or tool used. The result, shown in Figure 10, revealed that many preferred to send home some kind of game children could play with their parents, others opted to ask the parents to recap/review the session by making them use the same or very similar exercises to the ones used during the session. Worksheets were also a viable option, as well as reading stories or making use of strategies to include the exercises in the family routine. Interestingly, crafts (paper cut outs or drawings) were less used.

Regarding how SLTs check if the exercises were executed (besides noticing the child's speech and language development between sessions), a simple coding of SLTs' answers was used to analyse the data. Results, shown in Figure 11 revealed that most SLTs rely on feedback, possibly from an unreliable narrator due to age (child) or social pressure (parents). When asked "Do you think you have the necessary tools or means to check if the exercises were done correctly?", 16 respondents said No. The 8 that answered positively added that they would always check answers, use role-play, or even that, more important than checking the answers, was to check the achieved therapy goals. Some SLTs would like to use online tools or mobile apps, a digital service that would allow immediate notification of the SLT upon task completion by the child, with a log system to ascertain errors, time spent in exercises, errors (and solutions), and if there was any parent support. Most of the limitations presented were related with sound or video quality, how comfortable people were in front of cameras, and how these might impact the exercises.

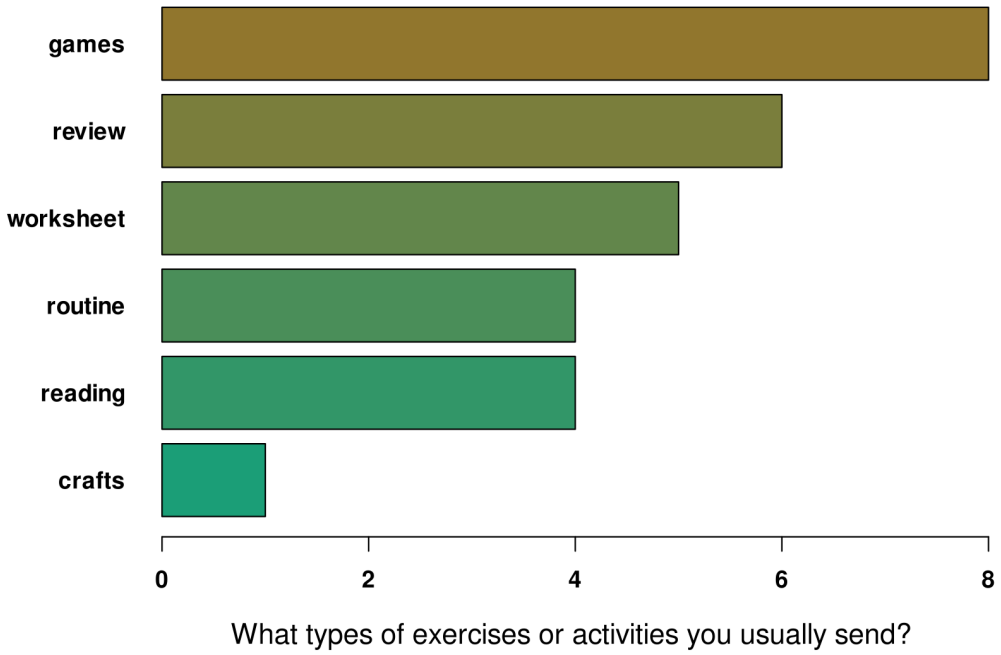

Figure 10. Most common type of activities or exercises sent home.

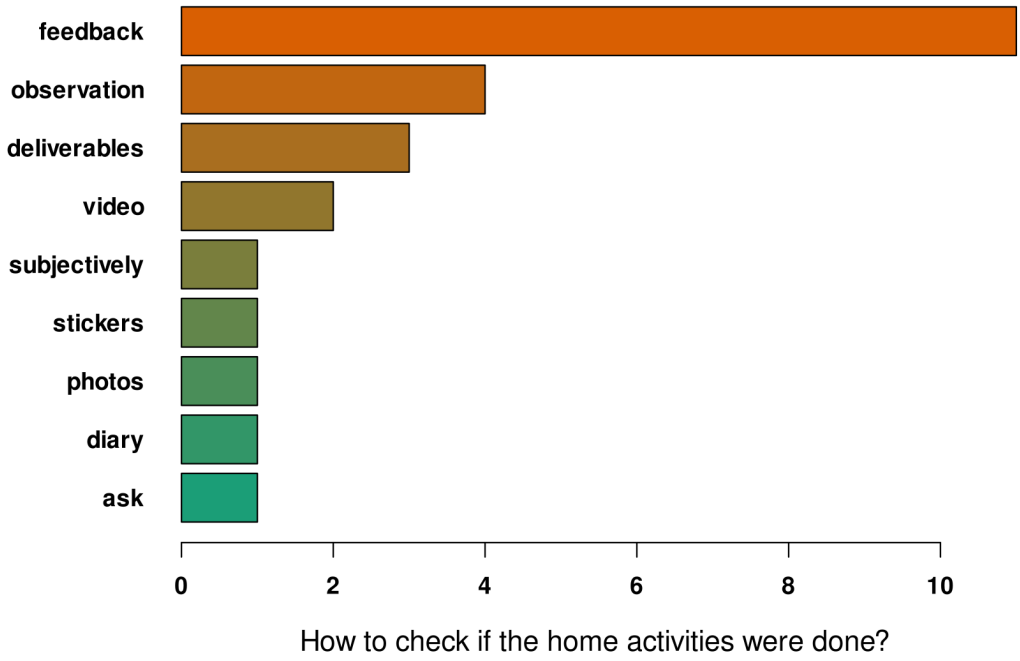

Figure 11. How do SLTs verify if the activities sent home were done?

Continuing to explore the home activities, we also tried to assess, through a Likert scale, the importance of having the possibility of verifying if the activities had been done and what difficulties the child might have encountered. No negative answers were given, with the majority of the SLTs answering that it is "very important" (16 answers) or "Important (6 answers). Throughout this subsection it was clear that being able to verify the execution of home activities was important, and also the importance and impact of involving the family.

Following these very positive answers, the next question asked what kind of difficulties the SLTs faced regarding the continuation of the intervention session at-home. Most of the answers mentioned the lack of time from parents, difficulties in coordinating routines, placing the focus on the SLTs or an excessive amount of school work. Some of

the answers also mentioned the lack of understanding from the parents of what is needed from them, parents reprehending children when they "underperform" in therapy, and the lack of adequate and timely clinical feedback regarding activity completion acting as a demotivation for some families.

The last part of the questionnaire focused on new approaches to intervention and continuation of the intervention session. All 33 participants were asked if they knew or used any tool similar to what usually supports telepractice, a term used here as placeholder of sorts, to try and determine how "at ease" were SLTs with technologies that allow at-a-distance intervention and to set the stage to discuss a new tool that would behave in a similar fashion. There was an overwhelming number of negative answers, with 27 SLTs saying they never used telepractice. The reasons alleged ranged from considering that face-to-face contact is preferable, or that the families do not have the technical skills or the resources to support a telepractice.

A final multiple-choice question, with a set of characteristics that they could pick and choose in order to define the ideal tool to support the continuation of the intervention at-home, was presented to the SLTs. As with previous data, a simple coding was used in order to reduce the answers to one-word descriptors, as shown in Figure 12. Difficulty refers to the tool permitting varying or adjustable difficulty levels; adjustable if the tool could adapt to the users' capabilities, e.g., fine motor skills; wholesome if it behaved as a family-friendly activity, that all can play and enjoy; reset referred to its ability to be re-set at-a-distance; the tool should create and send logs to the SLT without user interaction; and be simple as in simple to use—enabling low cognitive effort.

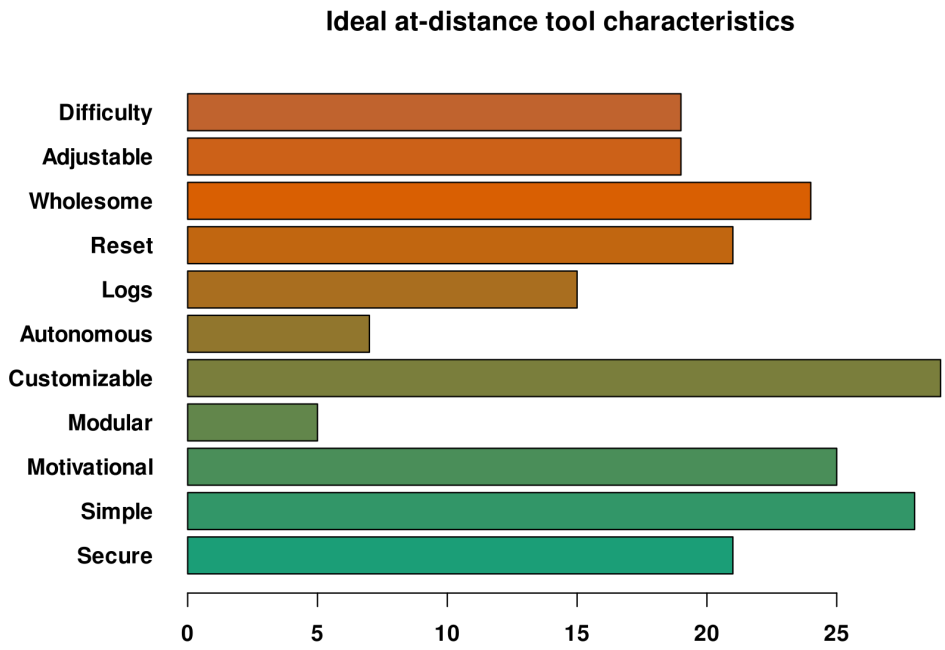

Figure 12. Set of characteristics that an ideal at-distance continuation of intervention tool should possess.

4. Discussion

This paper is a part of a larger study and aims to explore the potential of technology use, be it tangible media or internet of things artefacts, in a very specific context. This section will, follow, whenever possible, the same order in which the results were presented.

Regarding the literature review it is interesting to reflect on the amount of areas that address SSD, TUIs, or IoTs, as shown in Figure 4. Despite this abundance of areas and keywords, initial queries may not return any article or just a few. It can be said that the literature review evidences a sort of trend in using new technologies as they become

available to address children's SSD. However, results shown in Figure 5 revealed a balance in labels, that can be translated into areas: technology (with IoT, TUI, and applications), communication, ludic approach, the child, and home environment. All the areas play a part in advances and integration that could facilitate tool development. While in this literature review that balance may not have been apparent, due to the search terms used, for future queries this should be taken into consideration. Results from both the FG and questionnaire indicate that those areas also concern SLTs or are deemed very important for a successful intervention. The home environment and how to approach post-intervention in a ludic way while still improving communication with caretakers and children are areas that deeply interest and can impact SLTs' work.

Some limitations of reviewed studies included ignoring the need for social interaction with fully autonomous or semi-autonomous activities, i.e., without parents input or without turning parents into activity playmates [100,102,103,109,117,119]; assuming that a physical object used in intervention can retain the same value in a remote intervention [113] or not considering the opinions and inputs of children during the design and test phases [116], as well as the need to listen to SLTs and parents throughout the process [123].

The results obtained in the FG share similarities and concerns with the literature that was reviewed, namely, the desire for the artefact to be engaging [108,118], as well as capable of promoting social interaction [108], and to properly take care of security concerns [125,126], to name just a few. However, it should be noted that the results stem from a single FG and that this research would benefit from further discussion with SLTs and other relevant parties. As such, further FGs are planned and participants have been recruited. Due to the pandemic, as well as for time saving and commodity, future FGs will be held online using a collaborative software.

From initial FG results presented in this paper, several requirements and pitfalls or grey areas arose. These requirements were further divided into high priority to low priority tables, based on existing laws and regulations and difficulty to implement. The requirements in Tables 1–3 can be best contrasted with Figure 12, which suggested the ideal at-a-distance tool characteristics, and was created after analysing the questionnaire results. There is an initial mismatch between the FG and the questionnaire's highest ranked tool or artefact characteristic: Customisation. It can be argued, however, that these characteristics can be akin to customisation, and are present, albeit in medium to low priority tables, namely, enabling various difficulty levels, questions, and time to complete actions on a player per player basis, as well as enabling avatar creation. That mismatch disappears, with subsequent characteristics being equally chosen or referenced, although sometimes not by the same exact word, in both instruments or methods.

The questionnaire, despite attempts made to involve existing SLTs associations, had few full responses: Only 33 out of 114 SLTs fully answered it, meaning roughly 29% full participation rate. As noted, this may have been due to its length and the added chore of having to justify each answer. In hindsight, while collecting valuable information, this may have been detrimental. Perhaps an approach in which each question group was an independent questionnaire, presented as a follow-up within a week to a fortnight space in-between would have been preferable, as well as some mechanism to reward or inform the participants, in order to keep their interest and cooperation.

Despite the low response rate, the questionnaire was invaluable in highlighting the needs, the modus operandi of the SLTs, their desires and even reservations or fears regarding tools, such as TUIs for IoT artefacts. An interesting result from the characterisation of the respondents, already commented in the results section pertaining with the questionnaire was how skewed it was towards more experienced SLTs. Some questions that could arise due to this skewness are: Do more experienced SLTs have fears related to the use of technology in general (technophobia [129]), or some form of technology avoidance [130]? Or are they so engrossed in their usual practices that have proven to deliver results, and as such they are not interested in using new approaches? Despite the reported feelings, SLTs' when asked about ideal characteristics for a remote tool, did not refuse to answer,

and the answers denoted a careful consideration over the issue. This is to be explored in the forthcoming FGs.

In order to ascertain the degree of "fear" or technology avoidance, the technology acceptance model (TAM), developed by Davis [131], can be used. This model seeks to explain and predict how probable it is for an individual or an organisation to adopt new technology, based in 5 variables, namely, perceived use, perceived usefulness, attitude toward use, behavioural intention to use, and actual use [132]. There are external or independent variables that may impact the technology acceptance up to 60.2% [133], such as facilitating conditions, functionality and accessibility. Also of importance for this research, particularly regarding the design of the TUI itself, is the importance of a positive user experience [134,135] and how it adds up to the sense of usefulness [132] leading to a greater acceptance.

Speech and language therapists were evenly distributed between the main areas (Health and Education) of work, but there was a large number of SLTs working in the private sector, which influenced this study, namely, if SLTs can or cannot contact the family of a child. This is a factor to take into consideration when designing a prototype, particularly regarding testing and dissemination.

A common concern linked to the lack of interest in home-based intervention, was the limited amount of the child´s free time and time spent with the family. Interestingly, this concern was similarly voiced during the FG, both in the possible pitfalls (should not contribute to the feeling of wasted time) and in various activity requirements. The question of time and how children with SSD should use it was addressed in [124], and that study offers interesting observations to take into account in prototyping, such as the constant starting and stopping activities by children with SSD and problems of behavioural consistency, that may be caused by their communication problems and reasoning skills. In order to maintain focus and interest in the activity itself, it has to be versatile and customisable to allow sudden changes and features that enhance the activity, such as storytelling, game flow, and avatars.

We also looked into how SLTs perceived the importance of family involvement, how they acted to promote it and the need to train parents. Some of the SLTs' workplaces did not encourage family involvement, which may have been due to a variety of reasons, such as economic, social, or even lack of interest. Nevertheless, even in these situations, SLTs exchanged some information or instructions with the parents when they pickup up their children from the location where the speech and language therapy session had just taken place. Still, 14 SLTs answered that the family participated during the entire session, while 13 answered that the family participated at the end (when picking up the children) and 1 SLT reported participation at the beginning (when dropping off the child). Speech and language therapists considered that lack of time of family members, due to everyday or work occurrences, was a negative and detrimental factor, since it could mean limited family involvement.

The questions regarding the continuation of the intervention session at-home were particularly important to the goals of our research. The section started with a question supported by numerous references in literature, i.e, sending activities to be done at-home [11,17], receiving 24 positive and 4 negative answers. Interestingly, even the negative answers do not mean that no activity was promoted. These four SLTs preferred to contact the family directly and instruct them on how to change or adapt everyday routines into post-session activities, instead of using worksheets. This question had a follow-up regarding the types of activities sent, where games was the most common type of activity. This is quite understandable taking into consideration the typical age groups. When questioned regarding objectivity and how the SLTs could check if the child had done the activity, most SLTs seem to rely on feedback and observation, and infer if the work was done. While this is a viable solution, it has some shortcomings. Feedback depends on the details provided and the reliability of the person providing it. Parents knowing what is

socially expected of them might be tempted to be less realistic regarding activity execution, time spent on it and end results.

Speech and language therapists were also questioned about what tools they needed to check if the activities were done correctly. Most SLTs (16 in total) preferred simply to infer or ask the parents if the activities were done. Eight SLTs would use other means to check if the activities were being done, either by role-playing or assessing the new skills gained. The remaining questions in this section were related with the perceived importance of at-home activities and difficulties perceived by the SLTs. Some answers, revealed parents' lack of understanding of what was expected of them, blaming the child for "underperformance" and SLTs for inadequate and delayed feedback. These are questions stressed out by the FG requirements and the literature [101], that supported the use of features for real time reporting and possible activity re-set and feedback. The final section of the questionnaire further explored the concept of a new tool. It was, above all, a mechanism to gather, assess, and rank a set of ideal characteristics.

5. Conclusions and Future Work

In conclusion, the goal of this study was to understand what is being done to promote a better intervention or post-intervention approach for children with SSD, while being able to support parents and SLTs alike. The literature review revealed that some seek to answer it through technology while others through a social approach and/or gamified activities. It also became clear the richness of scientific areas involved but also how niche certain subjects can be. While more research is undoubtedly needed, a unified method or framework to address SSD intervention or post-intervention tools is lacking. There is a real desire from SLTs, expressed through the questionnaire, to have more and better tools, to be able to quantify and qualitatively grade the activities sent home. Activities have to allow personalisation, localisation and translation and above all, they cannot disrupt the home environment social fabric.

Regarding IoT and TUI and the briefly mentioned IoA, one has to be aware of existing different views on what TUI are, as well as proposed definitions [136] and the need to establish clear borders, previously defined by Ishii and Ullmer [44] in their seminal work "Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms", TUI are a form of interaction or interface with the user, allowing a richer and more natural exploration, experience, and data manipulation. Internet of Things devices, on the other hand, are the architecture or infrastructure, composed of sensors and actuators connected to the Internet that can retrieve, store, and transmit data, as well as control, at-a-distance, physical devices [137]. While IoT devices have some form of interaction (via a screen or keyboard, for example), some point to the still prevalent vendor centric approach, as opposed to the user or person centric approach, that forces the users to possess a certain degree of technological ease and familiarity with the technologies in use [138].

Therefore, TUI are the physical interface that we can use and that have been designed to give a rich user experience while allowing to control the IoT device, which is responsible for the data collection, storeing/manipulation and communication with the outside world via the Internet.

The complexity of IoT devices, available technologies and protocols have been previously discussed [79,139,140] and are outside the scope of this article.

For our IoA approach we have opted for a simplified approach of IoT architecture, commonly known as *Three Layer Architecture*, with the layers being [140]:

- (i) the *application layer*, responsible for providing the user with resources or communication protocols, specific to the user's needs. It allows effective communication with other applications or network;
- (ii) the *network layer* provides connection and communication with other devices. It can also be used for data processing in certain protocols such as fog, edge, or cloud computing;

- (iii) the *perception layer*, which is the physical layer, responsible for sensing and acting on the environment.

In Table 4 these layers are further expanded and TUI is introduced, creating the IoA. Brief explanations of what the layers may contemplate or connect to, are also included.

Table 4. Internet of artefacts with a three layer architecture.

Application layer	This is the layer in charge of outside communications. In the prototype that we are developing those communications will happen in the form of emails and possible remote login in the artefact. Probable technologies and protocols in use: - HTTPS; - email protocols.
Network layer	Security and communication layer; Due to low number of sensors and actuators involved it should be of low complexity; Data collected, while involving children will be anonymised. Probable technologies and protocols in use: - MQTT; - Wi-Fi/802.11.
Perception layer	Human interface—TUI: - allows direct manipulation and sensory experiences; - less interpretation; - collaborative uses; - can communicate to user changes in system by adjusting communication on monitor or the physical device itself. Probable technologies and protocols in use: - Raspberry Pi; - ESP32 Weimos D1 mini; - Push buttons, leds and other basic electronic parts.

This is by no means a final word on this vast and yet niche subject. More research is needed in various topics and a broader scope in the research, in order to gain a better understanding the needs of the end users, the varied approaches in speech and language intervention, and the impact interacting with technology can have.

Regarding future work, we will involve some end users, as advised by [121–123]. The end users invited for co-design will be SLTs, despite our initial plans to involve both children and parents. We acknowledge the complexity of designing "for" children as discussed in [13,141] as opposed to design "with" children [142]. However, time constraints with roots on the pandemic, difficulties accessing children until very recently due to pandemic related rules in pre-school, as well as funding, limited the co-design process.

After the sessions of co-design and brainstorming activities, already roadmapped by the initial FG perceived requirements, the prototype building and testing phases will begin. During these phases, usability and user experience, as well as technology acceptance have to be considered, designed for and evaluated. This prototype will then be tested in a controlled environment, with SLTs and children. Parents will also be invited to participate.

Due to aforementioned time constraints, user experience scenarios and tools, such as creating personas or composite archetypes and the definition of a context scenario [143] will not be developed. We will have to rely on the co-design process to help in defining clear goals. However, task analysis [143,144] will be implemented, if possible, at the controlled environment testing phase. While this task analysis activity will not be on time to refine the prototype, it can still provide valuable data to include in the framework.

We expect to have a suitable framework to guide future similar endeavours, with a set of design guidelines, technology pitfalls and acceptance validity assessment tools (questionnaire), identifiable post-intervention areas, activities more suited for this approach, and a final prototype.

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Abbreviations

The following abbreviations are used in this manuscript:

IoA	Internet of Artefacts
SSD	Speech and Sound Disorders
SLT	Speech and Language Therapist
TUI	Tangible User Interfaces
IoT	Internet of Things
GDPR	General Data Protection Regulation
M2M	Machine to Machine
FG	Focus Group
HCI	Human-Computer Interaction
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
TAM	Technology Acceptance Model

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