'INDRIYA' – PARTICIPATORY DESIGN OF A MULTI-SENSORY LEARNING AID FOR CHILDREN WITH COMMUNICATION DISORDER

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ABSTRACT

Designing for disability is a very specialised area as it requires interdisciplinary expertise, and designing assistive devices for children with communication disorder, is especially a challenge as these users are incapable of providing adequate and coherent feedback. With the adoption of participatory design approach, in collaboration with experts/professionals/educators, as pivotal stakeholders and a proxy for the end-users; a game-based, multi-sensory learning aid has been developed to train children on the concept of sense organs.Several concepts were generated and evaluated through special educator participation and based on a preliminary survey of external special educators as evaluators, the prototype was found to be suitable for the target user to enhance their communication skills. This paper captures a research through design perspective on the design of customisable solutions for beneficiary user groups, who are unable to offer feedback.

Keywords: Participatory design, Collaborative design, Design for X (DfX), User centred design, Design for Children with disability

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1 INTRODUCTION

Designing for disability (Hwang et al., 2018) is a very specialised area and requires interdisciplinary expertise, as designers need to consider parameters that make the intervention socially inclusive, functionally impactful, user-friendly, widely acceptable, and yet easy to access and afford in emerging economies, which have low-resource constraint settings. The use of assistive devices and technologies, in concurrence with available rehabilitation and treatment procedures, helps people with disabilities commune with society and live with dignity. However, designing assistive devices for children with disability, such as communication disorders, is a particularly herculean challenge, as these users are incapable of providing adequate feedback (Dursun et al., 2021). Nevertheless, the potential of augmentative and alternative communication (AAC) and other modes of assistive devices to make a transformational difference in the lives of those with highly complex communication needs is profound (Raghavendra et al., 2007; Butt et al., 2022) but is presently limited by the available learning aids in the market that do not respond to the specific needs of such children (Norrie et al., 2021). This, in turn, is supplemented by the clinical expert/rehabilitation professional who is a pivotal stakeholder in the rehabilitation process of the child (Guha et al., 2008).

In this research through design, an attempt has been made to investigate the soundness of the method of employing participatory codesign approach to collaborate, with secondary users who are pivotal stakeholders, such as experts/professionals/educators, as a proxy for the beneficiaries who are incapable of offering coherent feedback. The design of a game-based multisensory aid to teach the concept of sense organs was undertaken to explore this design approach, which is a culmination of participatory and co-design approaches.

2 LITERATURE REVIEW

2.1 Design for children with communication disabilities

Children have very unique perceptions of the world and ways to make sense of it. Developmental factors, means of acquiring valid inputs from children, and social interactions of children, are a few important considerations in designing interventions for children (Laschok et al., 2021; Dursun et al., 2021). In addition, design for children with disabilities requires knowledge, and pedagogical, psychological, and clinical insights, that such children don't have (Boyle et al., 2022).

Further to this, children with communication disorders may lack intelligent speech, which could be developmental or acquired, and often have physical, social, and intellectual disabilities (Raghavendra et al., 2007). This further limit the role children can play as full design partners throughout the design process (Tang et al., 2015; Lehnert et al., 2021; Gürbüzsel et al., 2022).

Once a child is detected with a communication disorder, the standard of care is audiological and cognitive assessments, with the intention to analyse the needs and support required for the child prior to beginning rehabilitation. Individualised Education programmes are often initiated for rehabilitation activities (Norbury et al., 2014; Rakap, 2015; Edemekong et al., 2017). Presently, assistive devices and technologies, and clinal experts/rehabilitation professionals/special educators are the two key aids for supporting children with communication disorders (Abirami et al., 2022).

2.2 Design of assistive devices and role of expert/professional/educator

Any object, equipment, software, or product system that is used to increase, maintain, or improve the functional capabilities of people living with impairments and disabilities, may be termed as an Assistive Device or Technology (Smith et al., 2018). The intent of these devices is to enhance the individual's functioning and enable independent living, thereby promoting well-being (Santos et al., 2018). Assistive Devices and Technologies are classified based on the complexity level of the technology used, materials, and operations they perform (Smith et al., 2018). However, devices that support one type of disability may be inappropriate or inadequate for others (Sharma et, al, 2020). While mass-produced devices, such as wheelchairs, hearing aids, etc. may be purchased off-the-shelf, certain assistive devices need to be customized to cater to a specific individual (Aflatoony et al., 2022). Even within the same category,

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sometimes the standard devices may not work for an individual, which leads to a lack of adoption of the device, in turn, hindering the rehabilitation aspect or the daily living of the individual (Gitlin et al., 1996; Buhler et al., 2015). Only when the needs and goals of the individual and the environmental factors along with patient conditions are blended in the design, will the assistive device be fruitful for the individual (Smith et al., 2018). Therefore, the context of the user's environment is very critical in the effective usage of assistive devices (O'Sullivan, C. 2021).

Designing customisable assistive devices requires consideration of the context of the patient and the clinical experts or the rehabilitation professionals, who are involved in the rehabilitation and therapy of the individual play a prominent role, as they provide the intimate information of the patients (McDonald et al., 2016). Literature reports that in the regions where there is a shortage of professionals, the lack of adoption and usage of these devices is very significant (Karki et al., 2022; Chen et al., 2022). In contrast, the professionals, as well as the beneficiaries, look for alternative solutions or seek modifications in the existing assistive devices (Aflatoony et al., 2020) so that they may respond to their particular needs, indicating a need for customisation (Magnier et al., 2010).

2.3 Participatory co-design approach

There have been significant efforts in exploring various collaboratory approaches for user-centric designs. Participatory (Pires et al., 2022), user-in-the-loop (Karia et al., 2018; Venkatesh et al., 2018), codesign (Scariot et al., 2012) and customer-centered design (Montignies et al., 2010), etc. are undertaken by multiple research groups, and evidence has been gathered from the literature to prove that the resultant design effectively brings out the users as the key focus. In the codesign approach, the end users actively shape the design process rather than being passive beneficiaries of the services. If the existing solutions are not catering to the specific needs, abilities, and contexts of users, the adoption of codesign approach serves as a promising choice (Couvreur and Goossens, 2011; Thorsen et al., 2019). Codesign approach has also been used to cater to problems where there is no feasible market solution due to their specific requirements (Buehler et al., 2014; Thorsen et al., 2019). Furthermore, co-design has been described, as an ideal choice in order to develop holistic solutions that consider the emotional, social, and cultural aspects of users thus serving as a humanistic approach that extends beyond functional needs and technical specifications (Sarmiento-Pelayo, 2015).

2.4 Research through design

While several avenues in robotics, game design, etc. have been ventured using co-design approaches, the design of assistive devices in resource-constraint settings for children with special needs is a relatively less explored territory (Gürbüzsel et al., 2022). Along with the inclusion of end users, there have been studies where multiple users and other stakeholders are involved in different facets of the design (Aflatoony et al., 2020; Gürbüzsel et al., 2022), and as the literature indicates, the clinical expert/rehabilitation professional is a pivotal stakeholder, as well as aid, in the rehabilitation journey for the child (Abirami et al., 2022).

The objective of this paper is to investigate the virtue of using participatory design in collaboration with the secondary users/stakeholder, i.e., the clinical expert/rehabilitation professionals, to explore customisable solutions for the end-user/beneficiary, i.e., the children with communication disabilities, and in turn, elucidate the requirements and affirm the inputs required for designing an assistive device for the beneficiaries, in the Indian context.

3 DESIGN PROCESS

3.1 Design methodology

The design process was undertaken at an urban rehabilitation centre that caters to children with multiple disabilities, and the Design Thinking methodology was followed, with elements of participatory and codesign. During the 'Empathise' stage; discussions, observations of training and therapy sessions and interactions were conducted to understand the objectives and prerequisites of these units and programs.

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Since the age group, capabilities, and requirements in each unit varied; to 'Define' the intervention, the scope was narrowed to target the Special Teaching Unit (STU), which caters to children between 3to 9 years who require high support in most of the development stages,
Then on, 'Ideate, Prototype, and Test' was pursued, through a participatory design approach with the secondary user, the clinical expert/rehabilitation professional, instead of the end-user, i.e., the beneficiary children.
Additionally, the extended taxonomy of game design, as proposed by Bhatt, Acharya, and Chakrabarti (2021) was found as a relevant guide to develop the final solution, and the following categories were adopted, namely, Game approach, Type of Platform, Targeted user, Placement of game, Game purpose, Involvement of participants, & Evaluation.

3.2 Design context: Rehabilitation and therapy methodology

Creating awareness among children about themselves and their environment, making them cooperate with their parents, teachers, and caregivers in all the Activities of Daily Living, and developing communication skills in them according to their respective abilities are major objectives of the special teaching unit of the centre.
Before the admission, several assessments are carried out to understand the child's capabilities in different facets like cognition, physical capabilities, etc. A multisensory approach is undertaken, and activities are planned based on the child's capabilities. Various stimulations (Auditory, Tactile, Gustatory, Visual, Olfactory, and Kinesthetics) are provided during activities. This approach enables students to understand their immediate environment.

3.3 Empathise and Define: Identifying the needs and design inputs through a participatory design approach

The rehabilitation professional, in this case, the special educator who trains the children every day, understands the needs, knows the existing abilities of the child, and has the expertise in training these children were interviewed. The objective of the interview was to understand the nuances of the training process, abilities, and existing skills of children with respect to cognition, communication, motor skills, etc., to aid in the design process. The interview questions were open-ended and focused to gain insights into the daily activities of children in the rehabilitation centre, training materials used, challenges faced by various stakeholders in the training process, requirements for the new design intervention etc. The following are a few key observations and insights gathered through semi-structured interviews with stakeholders, mainly the rehabilitation professionals/special educators associated with the target group, prioritised below in (Table 1);

- Children could recognise shapes, colours, etc.
- Motor skills observed among children were the ability to point, pull, insert and hold an object with two fingers.
- Various 'Ready Made' Teaching Learning Materials were used in sessions.
- Peg boards, blocks, single-entity toys, boards, flashcards, etc. currently used during the training were restricted to only visual stimulus
- These off-the-shelf toys were not suitable for all the children belonging to the group.

Table 1. List of prioritised requirements (top three)

Priority	Requirements from special educator (secondary user/stakeholder)
1	Multisensory aids to enhance communication skills must be used
2	The gamified approach must be employed in the training
3	Customisable aid catering to the abilities and needs of the child is required

The defined need was for an intervention that, enhances the communication of the children, whilst ingraining and reaffirming the learning concepts, through a multi-sensory aid, that is game-based.

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3.4 Ideate: Multi-sensory, game-based learning aid

After understanding the needs and abilities of children, and defining the requirements, the following steps were adopted for ideation, as in Figure 1.

The first step was identifying the tutoring concept to be implemented in the design. Based on interactions with the special educator of the unit, teaching sense organs using multisensory stimuli was selected, as this is a very essential part of the training curriculum of these children. Along with tutoring a particular concept, in this case, the sense organs, the design intervention must fulfill other key functions based on the captured needs and requirements. The key functions of a multisensory aid are generating the stimuli, tracking the response of the child to the stimulus, acknowledging the response, and generating positive reinforcement for every correct response of the child.

Different ways of achieving these functions were conceived through multiple concepts (as in Figure 2).Each concept has different combinations of the interaction of the child with the aid (press, remove, fix, etc.), variations in the placement of different components of the aid, embodiment design etc are also found between the concepts. Insights obtained from the special educator, gauging the feasibility based on the abilities of the target children to use and interact with the aid while performing a specific task were considered to finalise a concept, and reject other concepts which did not fit into the above criteria.

The chosen concept (as in Figure 3) was detailed out as a system comprising of a mobile application or an interface, integrated with a hardware aid. The hardware aid generates multi-sensory stimuli based on commands from the mobile interface and the child needs to acknowledge the receipt of the stimulus by pressing a button on the aid. Reinforcement is provided for every correct response of the child in form of a blinking green light.

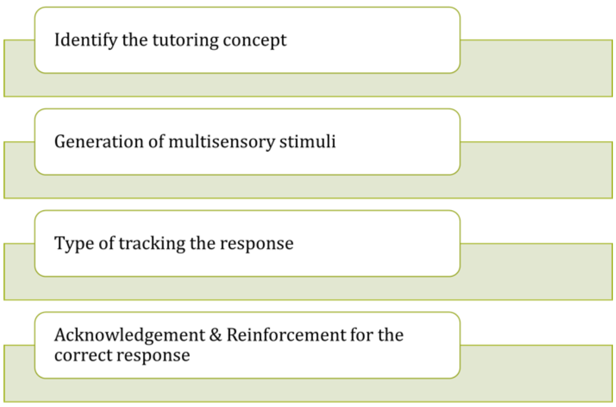

Figure 1. The process adopted for ideation

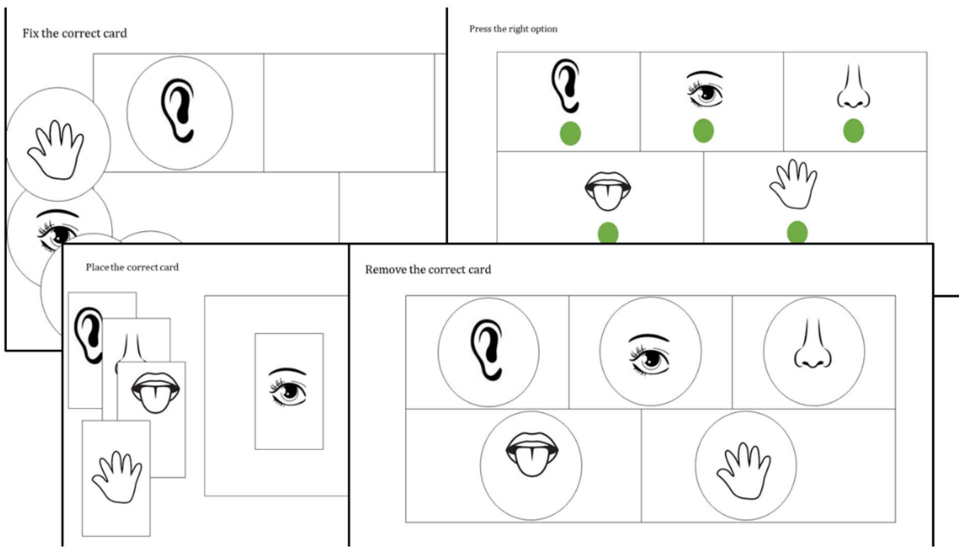

Figure 2. Illustration of other ideated concepts

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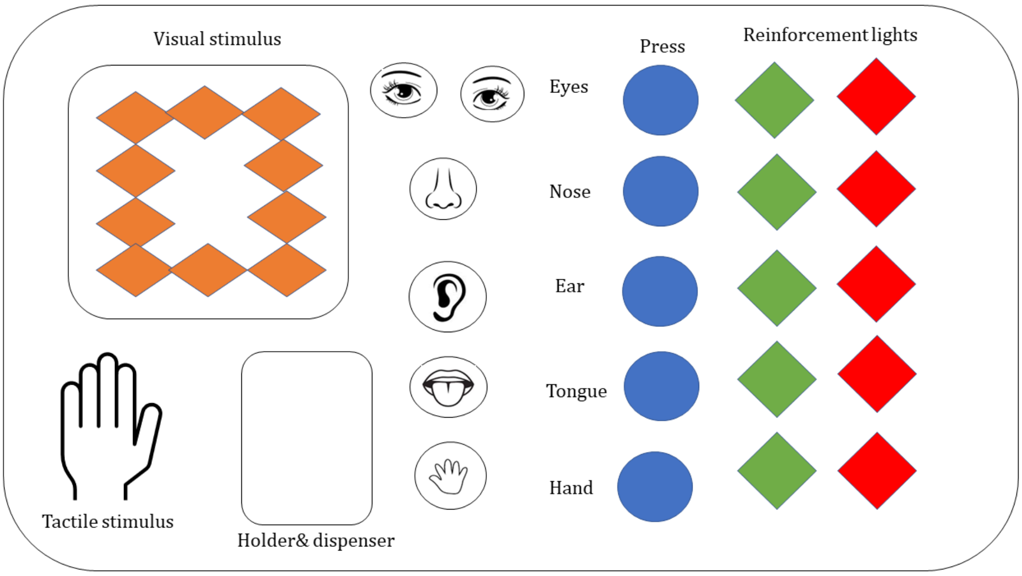

Figure 3. Illustration of the chosen concept

3.5 Prototype

A prototype of the concept - mobile interface and the hardware aid was developed. Visual stimulus in form of lights patterns, sounds for auditory stimulus, vibration for tactile stimulus, and provision for olfactory and, a gustatory stimulus were used as multisensory input stimuli. Tactile push buttons were chosen to track the responses of the child. Positive reinforcement in form of green light was included for every correct response and the response is communicated back to the mobile interface. The interaction between the mobile interface and hardware is established through Bluetooth communication.

The first version of the prototype was taken to the rehabilitation centre for initial feedback and input after its development. Changes in colour schemes of reinforcement, position to feel the tactile stimulus, etc were suggested by the special educators. The child was made to interact with the device after obtaining the consent of the parent and the special educator in their presence (Fig 4). Simple tasks such as pressing different push buttons which are used for tracking the response, and placing the hand on a provision to detect tactile stimuli were considered for initial testing and feedback. The nuances related to the positioning of the push buttons, the spacing between each type of interaction, the size of the embodiment, etc were iterated, based on the feedback obtained through this participatory approach to design. The changes suggested and observed were incorporated into the next version of the prototype. (Fig 5).

Figure 4. Feedback on the initial prototype (Left to right: educator, the child, the parent)

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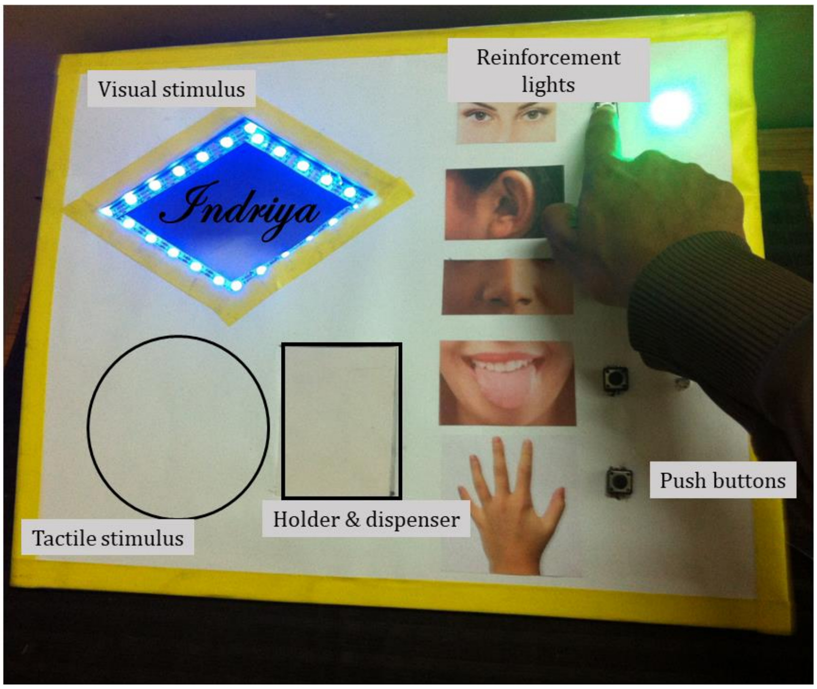

Figure 5. Developed prototype

3.6 Preliminary validation and test results

The overall concept behind the design and the prototype device was subjected to preliminary validation by 5 special educators who were not part of the participatory design process. This was done to ensure valuable feedback is received and incorporated before a rigorous, long-drawn clinical investigation. The concept was explained to the evaluators and the prototype was demonstrated, against which they were asked to respond to seven survey items identified (listed in Table 2) on a 5-point Likert scale.

The results plotted in Figure 5, overall indicate agreement across all the seven survey items, marked as either - Strongly Agree, Agree, or Neutral, by the five evaluators. While the survey items 1,2,4 and 7 have a consistent agreement, survey items3,5 and 6 elicited a neutral response.
Additionally, right after the survey, the evaluators commented that for the survey items that they marked as 'neutral' requires longitudinal study to yield confident response; and offered feedback related to expanding the concept to teach other concepts.

Table 2. Survey Items formulated for evaluation

#	Survey Items
1	The device serves as a multisensory teaching learning material for the targeted children.
2	The activity implemented in the device is useful in training the child in sense organs.
3	The multi-sensory stimuli provided through the device is suitable for the targeted children.
4	The device serves as a platform for the instructors and caretakers to train the child in various stimuli.
5	The device provides provision to customise the stimuli based on the child's need and capabilities.
6	The adopted gamified approach to training will increase effectiveness.
7	The training of the adapted concept and skill in the device will pave way for improving the communication skills of the targeted children in the longer run.

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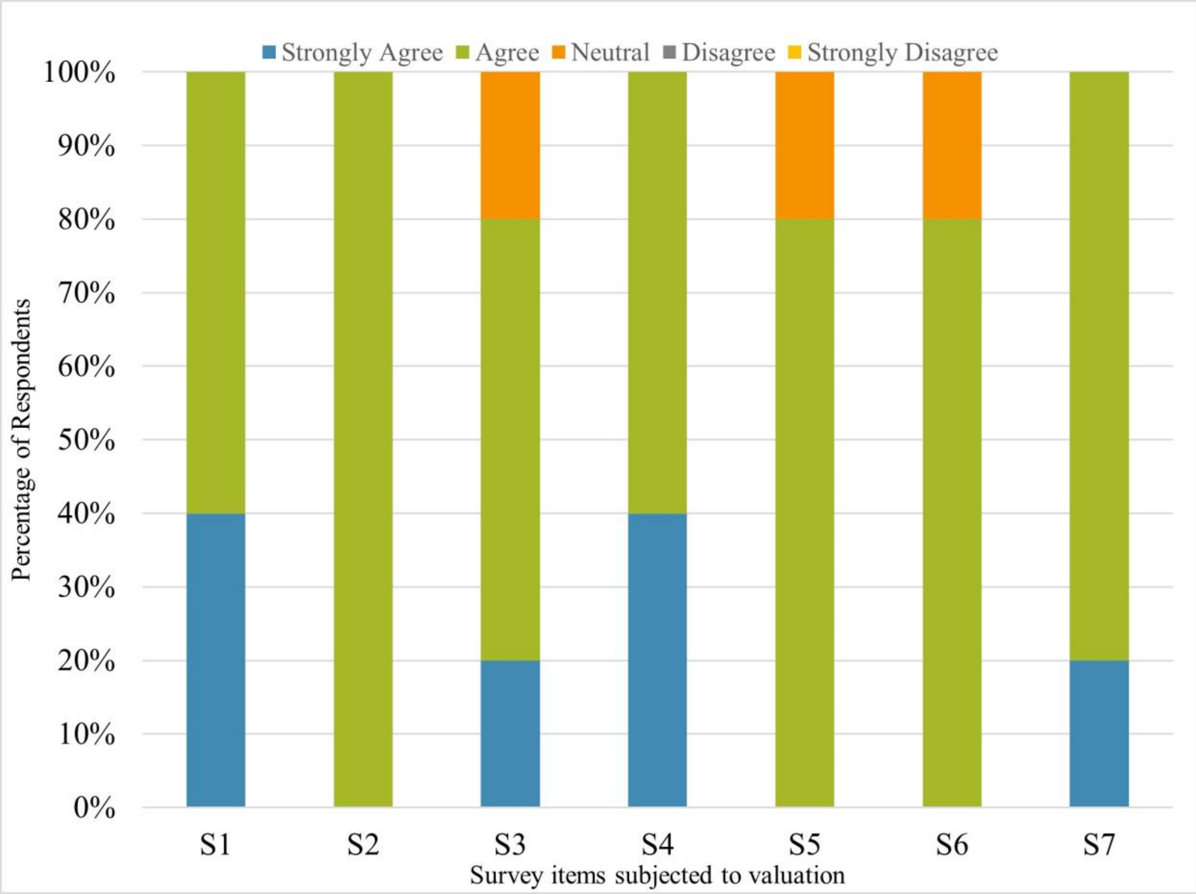

Figure 6. Summary of evaluation

4 SUMMARY AND DISCUSSIONS

This paper investigates designing customisable solutions for children with communication disorders via the adoption of participatory codesign approach with experts/profes
sionals/educators, as pivotal stakeholders, as well as a proxy for the end-users due to their inability to offer coherent feedback. A game-based, multisensory learning aid was developed to train the children on the concept of sense organs, using different sensory stimuli (auditory, visual, tactile, olfactory, and gustatory), and the same was used by the children under the supervision and direction of the special educator, while observed by their parents. The prototype device, and its overarching concept, was found to be meeting its stated goals, based on a preliminary survey of special educators, who found the solution to be suitable for the target user to enhance their communication skills.

Apart from showcasing the soundness of using the participatory codesign design method to design for such circumstances where beneficiaries are not able to provide feedback, this study highlighted the roles of various stakeholders involved in the rehabilitation journey of a child with communication disorders. The special educator was involved in explaining the training curriculum and adopting the same for the design intervention, such as choosing the interactions of the child with the designed system, based on the existing abilities of the child (motor skills, cognitive skills, etc.). The needs and capabilities of the child were also affirmed, and valid inputs and choices were given by the special educator throughout the concept design and prototyping phase. The validation from the external evaluators, who were also experts in this domain, indicated that the proposed concept satisfied the requirements identified.

A limitation of the work is that the children were not directly involved in collecting feedback during the validation process, given the premise. However, the children showed excitement and through

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'reaction', a sub-category for 'Evaluation' of a game (Bhatt, Acharya & Chakrabarti, 2021), implicitly expressed positivity. This could be a promising future direction to explore the other aspects of user-centered beyond the effectiveness of the learning, such as, 'fun' - a key element for any game, and associated incentives, that have the potential to make the engagement and the design more robust.

Presently, an iteration of the device, considering the received feedback and other important criteria, such as affordability with respect to the Indian context and 'fun' for prolonged usage, is underway. Future work entails further validation across a larger sample size and in diverse demographics within the low-resource constraint setting, and investigations into the role and participation of multiple stakeholders, in designing for children with disabilities. This paper stems from a larger body of research, through the lens of design, keen on exploring various design approaches for Design for children with disabilities, in low-resource constraint settings.

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