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Original articles

Web app for the stimulation of auditory skills in children

Aplicación web para la estimulación de las habilidades auditivas en niños

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Abstract

The existing literature identifies various situations related to hearing problems in children, such as difficulties in understanding oral language, delayed speech development, or auditory discrimination problems. In this work, we present a technological tool designed to stimulate listening skills in children from 5 to 7 years old, following the principles of Condemarin. This tool offers stimulation activities and provides immediate feedback to improve the ability to recognize, discriminate, and interpret auditory stimuli, which contributes to the development of communication skills in children. The tool we developed is a web application that is easy for therapists to install, learn, and configure. For its creation, we follow the prototype methodology, which includes the requirements, assembly, evaluation, corrections, documentation, and testing stages. We collaborate with a multidisciplinary team of experts in information technology, linguistic rehabilitation, education, and graphic design. Throughout the six phases of our process, we kept user needs in mind, resulting in a system evaluation that demonstrated high user satisfaction and good performance both in technical and interface terms. In addition, this application benefits children with language disorders and learning difficulties and children from 5 to 7 years old since it encourages the development of their communication skills.

Keywords: Auditory software, aural skills, prototype for listening skills, stimulation software, web app.

Summary: Introduction, Methods, Results of the instantiation of the methodology and Conclusions.

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Resumen

En la literatura existente, se identifican varias situaciones relacionadas con problemas auditivos en niños, tales como dificultades en la comprensión del lenguaje oral, retrasos en el desarrollo del habla o problemas de discriminación auditiva. En este trabajo, presentamos una herramienta tecnológica diseñada para estimular las habilidades auditivas en niños de 5 a 7 años, siguiendo los principios de Condemarin. Esta herramienta ofrece actividades de estimulación y proporciona retroalimentación inmediata para mejorar la capacidad de reconocer, discriminar e interpretar estímulos auditivos, lo que contribuye al desarrollo de las habilidades de comunicación en los niños. La herramienta que desarrollamos es una aplicación web de fácil instalación, aprendizaje y configuración para los terapeutas. Para su creación, seguimos la metodología del Prototipo, que incluye las etapas de requerimientos, montaje, evaluación, correcciones, documentación y pruebas. Trabajamos en colaboración con un equipo multidisciplinario compuesto por expertos en tecnologías de la información, rehabilitación lingüística, educación y diseño gráfico. A lo largo de las seis fases de nuestro proceso, tuvimos en cuenta las necesidades de los usuarios, lo que resultó en una evaluación del sistema que demostró una alta satisfacción de los usuarios y un excelente rendimiento tanto en términos técnicos como en la interfaz. Además, esta aplicación beneficia tanto a niños con trastornos del lenguaje y dificultades de aprendizaje como a niños de 5 a 7 años, ya que fomenta el desarrollo de sus habilidades de comunicación.

Palabras clave: Aplicación web, habilidades auditivas, prototipo de habilidades auditivas, software de estimulación, software auditivo.

Introduction

The World Health Organization (WHO) has identified significant barriers to access to speech and language treatment in terms of cost, long-term participation, and difficulty in extending interventions beyond the context of telemedicine. Several studies have explored using systems to overcome these barriers through technology with untapped potential to address these issues, enabling them to access quality rehabilitation services through their necessary resources. Telemedicine uses information and communication technologies (ICT) to provide remote medical services, allowing medical consultations, diagnoses, treatments, and follow-ups to be performed digitally. This may include using medical devices connected to the Internet, video conferencing, email, messaging, and other communication tools (Gačnik et al., 2018; Morales-Acosta, 2020; Spitale et al., 2021).

These technologies aim to help people improve access to information and communication through specific devices and programs. Interventions for speech therapy therapeutic purposes using technological means, whether virtual platforms and/or software programs, have shown significant improvements in the linguistic, cognitive, social, emotional, and behavioral development of people in therapy, evidencing the increase in motivation and participation in different therapeutic activities, mainly playful, whether these are in teleconsultation or in virtual platforms or applications in electronic devices, which in turn has affected behavior, both personal and in the ability to analyze and detect behavioral patterns in other people (Buitrago et al., 2019; Gerosa et al., 2009; Spitale et al., 2021; Walden, 2021).

Speech-language pathology is a medical discipline dedicated to studying, diagnosing, and treating problems related to speech, language, hearing, and balance (Isaías & Campra, 2021).

Telemedicine, for its part, has allowed speech and language pathologists to reach patients who live in remote areas or who have difficulties traveling due to physical or cognitive

disabilities. To guarantee the quality and safety of the services provided, it is essential to regulate telemedicine and remote practice with the support of assistive communication technologies, such as screen readers, adapted keyboards, voice synthesis devices, and sign language translation software, which can help people with disabilities improve their access to information and communicate with others (Acosta et al., 2020).

Literature Review

The Internet has revolutionized many areas of modern life since it became a global means of communication. Information and Communication Technologies (ICT) offer the option of analyzing, organizing, synthesizing, and transmitting information and, therefore, can contribute to expanding and developing valuable clinical and educational tools for speech and language (Toki et al., 2012). In addition, it allows us to offer personalized and quality service (Lavoie et al., 2020).

"Simone Says" is computer software designed for children with ASD to acquire functional language through an interactive environment for language recovery that brings together research on speech recognition, natural language processing, and computer-assisted instruction, allowing concentration and primarily visual and auditory memory to work (Lehman, 1998).

The study of Glykas and Chytas (2004) describes the first web-based tool called Telelogos for diagnosis, treatment, and digital learning in speech and language therapy. It consists of three modules: public awareness, referral, and evaluation, which allow speech therapists and other professionals to find the optimal treatment for each patient. The tool was evaluated by twenty speech and language therapists and tested by potential users in Greece and the UK. The evaluation results were encouraging and demonstrated user satisfaction regarding efficiency and functionality. According to Griffiths et al. (2007), "high user satisfaction" means that users or customers of a product, service, or experience are very satisfied or pleased with it. High user satisfaction typically indicates that people find the product or service to be effective, enjoyable, and meeting their expectations or needs. It suggests a favorable response from the users, often seen as a desirable outcome for businesses and organizations aiming to provide quality products or services.

The authors, Pierrakeas et al. (2005), present the use of collaborative online environments (telemedicine) for speech therapy, in which the therapist can guide the group of participants through structured discussions, focusing on improving the initiation of speech. Conversation, taking turns, clarifying ideas, repairing breaks in conversation, and participating in role-plays of everyday communication situation. In addition, these environments employ easy-to-use recording, editing, and storage functions, so users can create professional recordings at their own pace in industry-standard formats using a standard computer with a camera and speakers. One benefit of these online collaboration environments is that they can support an unlimited number of co-presenters and subject-matter experts.

Toki et al. (2012) developed an online speech-language pathology expert system for diagnosing speech disorders and difficulties. The system can answer specific questions, give an automatic evaluation response, and generate a list of localized disorders. SLPs and other professionals can use this feedback to plan therapy or learning tasks.

There is a large amount of research regarding methods and technological resources implemented in speech therapy. The most commonly used technological resources are video calls, 2D and 3D resources, multimedia, voice recognition, and speech-to-text for patients to

obtain the necessary feedback for the correct development of the therapeutic session. Several investigations suggest that these tools are most accessible and convenient for everyone (Lo et al., 2017). In addition, they support patient-centered and self-management models of medical care (Madeira et al., 2017), significantly influencing the socio-emotional, motivational, and cognitive aspects (Buitrago et al., 2019).

In work carried out by Buitrago et al. (2019), a technological device is presented to support the therapeutic processes of children with learning problems to develop the following skills: memory, concentration, mathematical operations, laterality, and spatial orientation. The device consists of a mobile application for Android devices, three hardware interfaces, and a Lego mobile robot. The app has three activities (challenge, math, and maze). After the validation, it was possible to confirm an improvement in the children's abilities in the activities (memory, concentration, mathematical operations, laterality, and spatial orientation), as well as improvements in their self-esteem and general performance.

The main objective of the study by Lavoie et al. (2020) was to investigate the efficacy of a self-administered therapy for people with primary progressive aphasia (PPA) using a smart tablet to improve function word naming and assess generalization to a conversation task. The treatment was administered to five adults diagnosed with PPA four times a week for four consecutive weeks. As a result, a significant improvement was determined for the trained words in the five participants, and the gains were maintained two months after the treatment in four of them. In addition, evidence of generalization in conversation was found in three participants. Two aspects of the system stand out: i) a self-applicable type of therapy can be carried out where the person has control over their therapeutic process and their subsequent performance, and ii) it makes it possible to keep a detailed record of the evolution of the patient in different aspects of the therapy.

In the study carried out by Catania et al. (2022), a system was designed and developed that encourages children to describe themselves through questions and suggestions to create an avatar consistent with what is said, thought, and seen in reality, allowing the user to have a positive impact in different areas such as i) self-awareness, ii) self-knowledge, iii) communication skills, and iv) vocabulary of the mother tongue and foreign language.

Besides, Condemarín et al. (2016) identified five critical areas of auditory stimulation: i) Sound Recognition Stimulation, Activities to identify and recognize diverse sounds, strengthening hearing capacity; ii) Stimulation of Auditory Discrimination: Development of the ability to differentiate similar sounds, improving speech comprehension; iii) Sound Localization Stimulation: Helps determine the direction of sounds, crucial for spatial awareness; iv) Stimulation of Auditory Comprehension: Improves the interpretation and processing of auditory information, facilitating communication; and v) Stimulation of Auditory Memory: Reinforces the retention of auditory information in the short and long term.

Regarding this software, there is identified software with similar purposes available on the market. Among others: i) Lingokids is primarily focused on learning the English language and providing an engaging educational experience for children; ii) CogniFit is an application that offers auditory stimulation exercises and other cognitive activities to improve general auditory and cognitive skills. This app is available in multiple languages, including Spanish, and offers a free version with limited features and a paid version that provides complete access to all features and exercises. iii) Auditory Processing Studio is an application designed to help people with central auditory processing difficulties. It provides a variety of ear training exercises and

is available in multiple languages, including Spanish. This app offers a free trial version, but it also has a paid version with additional features and more advanced exercises.

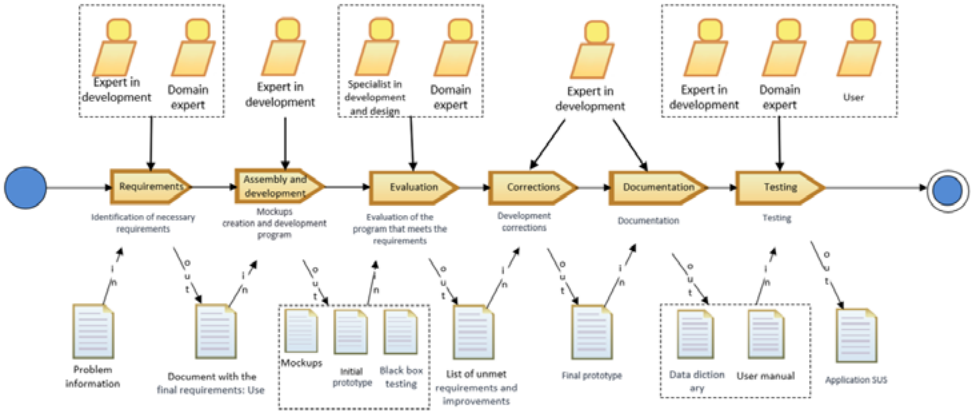
Methods

The prototyping methodology allows the developer to create, refine, and test a working version. Despite the increasing focus on the detailed and controlled administration of the design process of a system, the prototyping methodology could offer data on the application's performance generated in the design phase (Armenta Benitez et al., 2018).

The prototype model of Armenta Benitez et al. (2018) was considered to develop the software prototype that supports the stimulation of auditory skills in children from 5 to 7 years old. Figure 1 (SPEM 2.0 (OMG, 2008)) visualizes the methodology applied in the construction of the prototype. This methodology consisted of six phases: i) Requirements, ii) Assembly and development, iii) Evaluation, iv) Documentation, and v) Testing.

Figure 1

Stages of the prototyping methodology



Results of the instantiation of the methodology

Requirements Phase

The Requirements phase is developed in a unidirectional way between three activities adapted to the domain of this study (Amado-Salvatierra et al., 2015): i) definition of the problem, which includes i) defining the auditory stimulation program (guidelines proposed by Condemarín) and formulate the objectives to be achieved; ii) identification of requirements: identify the activities to be carried out, define the rules to be followed to guarantee accessibility/ usability, and select or create graphic and multimedia resources, for which the use case diagram was defined; and iii) use cases: where the requirements for the implementation of the prototype are defined. As a result of this phase, the use cases were defined based on the use case diagram and stimulation modules, as shown in Tables 1 and 2 and Figure 2.

Table 1

Stimulation modules

CODE	STIMULATION MODULES	DESCRIPTION
ACT1	Module 1 Activities	Auditory memory
ACT2	Module 2 Activities	Auditory Awareness

CODE	STIMULATION MODULES	DESCRIPTION
ACT3	Module 3 Activities	Auditive discrimination
ACT4	Module 4 Activities	Initial sounds
ACT5	Module 5 Activities	final sounds

Figure 2

Use Case Diagram

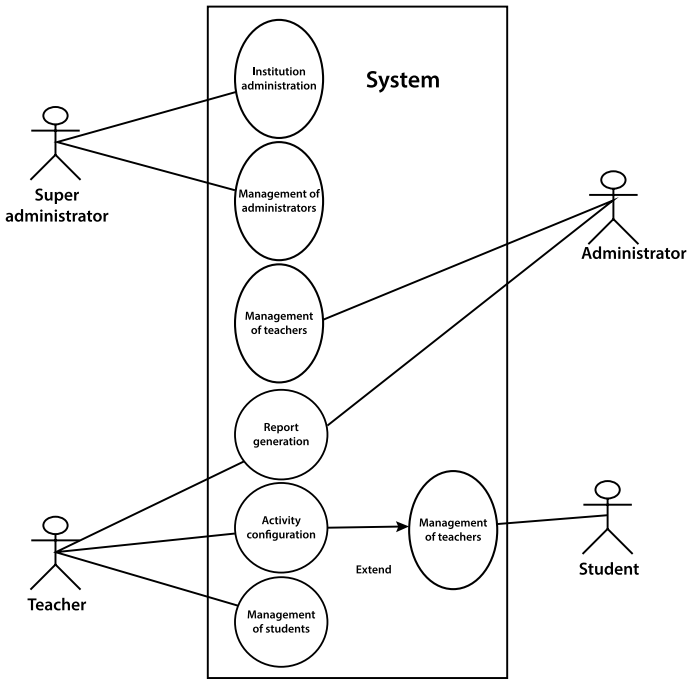


Table 2

Use Cases

Code	Case of use	Actor	Description	Priority
CU1	Administration of Institutions	Super Admin	It allows one to take control of the different institutions.	Mandatory
CU2	Management administrators	Super Admin	It allows one to take control of the different administrators who will take control of the platform.	Mandatory
CU3	Administration of teachers	Administrator	Allows one to take control of the different teachers who will take control of the stimulation activities.	Mandatory
CU4	Generation of reports	Administrator, Teacher	It allows one to take control of the reports, with the results for the students when carrying out the activities. Stimulation.	Necessary
CU5	Configuration of stimulation activities	Teacher	It allows one to configure the necessary stimulation activities for students (ACT 1 - ACT 7).	Mandatory
CU6	Carry out stimulation activities	Students	It allows one to carry out the stimulation activities generated by the teacher (ACT 1 - ACT7).	Necessary
CU7	Student Administration	Teacher	It allows one to keep track of the different students who carry out the activities. Stimulation.	Mandatory

Assembly and development phase

Based on use cases, the second phase was developed unidirectionally between two activities adapted to the domain of this study: i) Assembly and ii) Development (Amado-Salvatierra et al., 2015). In this way, a generic plan was created for how the software will be

built, which includes choosing the optimal instructional method or methods to create objects or materials that help support the therapeutic processes of children with learning disabilities (Buitrago et al., 2019).

Assembly Activity: As a result of this activity, the interfaces (mockups) were designed for the activities ACT1 to ACT7.

Development Activity: The architecture used to implement the web prototype is based on the Model View Controller (MVC) (Rojas et al., 2019). The implementation of this model was based on the platform (Yii, PHP, MARIADB, speech recognition, and the Visual Studio Code IDE) to develop a web application compatible with mobile devices, tablets, and computers. As a result of this activity, the first version of the software prototype was obtained with the Use Cases CU1 to CU7 implemented. During the internal tests of the software among the developers, performance evaluations were made for each implemented item. As an output, the partial solution software prototype was obtained.

Evaluation Phase

The evaluation phase is carried out in a unidirectional way between three activities (Amado-Salvatierra et al., 2015) adapted to the core of this study: i) Planning the evaluation; ii) Gathering information; iii) Analysis of the information obtained. These activities determine if the software prototype achieves the planned objectives and what changes are necessary.

For this phase, it was considered necessary to evaluate the requirements fulfilled and the system's functionality through the type of software tests known as "black boxes". The input was the first version of the prototype obtained in the previous stage. The checklists for evaluating fulfilled requirements and functionality were based on the model (Aristegui, 2010). Tables 3 and 4 show the compilation of the evaluation carried out by the expert in the field of speech therapy.

Table 3

Requirements Assessment Checklist

Requirements	Met the requirement		Comments observations
	YES	NO	
The system will allow the creation of different stimulation activities the teacher generates.	X		Works correctly
The system will allow one to view the options of each stimulation activity randomly.	X		Works correctly
The system will allow one to reproduce the texts of the answers in audio form.	X		Works correctly
The system will allow the playback of the audio files uploaded by the teacher to stimulate the activity.	X		Works correctly
The system will allow, through voice recognition, to select the response of the stimulation activity in the form of an image.	X		Works correctly
The system will allow, through voice recognition, to say the answer.	X		Works correctly
The system will allow visualizing feedback between each stimulation activity.	X		Works correctly

Note: Table 3 provides eight successful sample request requests that can be performed on the prototype. Therefore, the success rate for evaluating fulfilled system requirements is 100% (Sasmito & Nishom, 2020).

Table 4

Functionality Assessment Checklist

Action	Scenery	Met the requirement		Comments observations
		YES	NO	
Does the system start without a problem?	The student enters his username, password, and institution	X		Works correctly
	The student presses continue and is redirected correctly.	X		Works correctly
	The student accesses the system.	X		Works correctly
Does the system display the correct information?	When accessing the system, the correct student information is displayed.	X		Works correctly
Does the system allow stimulation activities to be carried out correctly?	Auditory awareness module.	X		Works correctly
	Auditory memory module.	X		Works correctly
	Auditory discrimination module.	X		Works correctly
	Initial sounds module.	X		Works correctly
	Final sounds module.	X		Works correctly
Does voice recognition work correctly?	By pressing the voice recognition button, an answer can be selected .	X		Works correctly
In stimulation activities, does the system reproduce the orders?	Pressing the play button plays the command.	X		Works correctly
Does the system show feedback on the stimulation activities carried out?	Upon completing the stimulation activities, it displays a message with "Well done."	X		Works correctly
	At the end of the stimulation activity, it shows the general result.	X		Works correctly
Does the system display the information according to roles?	Super Admin	X		Works correctly
	Administrator	X		Works correctly
	Teacher	X		Works correctly
	Student	X		Works correctly

Note: Table 6 provides seven successful sample actions that can be executed on the software prototype. Therefore, the success rate for the functionality of the system is 100% (Sasmito & Nishom, 2020).

During the evaluation, five observations for improvements are listed in Table 6.

Table 5

List of improvements

Improvement number	Improvements to perform	Roles affected
1	Correction of the list in user report module: Display a list of users in the user report.	Super Admin Administrator Teacher
2	Filter correction in the general report module: Implement a search engine in the general report to filter the report by a teacher.	Super Admin Administrator Teacher
3	Correction of the list in the general report module: Implement a table in the general report to view the teachers.	Super Admin Administrator Teacher

Improvement number	Improvements to perform	Roles affected
4	Correction of information in the general report module: Eliminate unnecessary data in the general report.	Super Admin Administrator Teacher
5	Correction of behavior for teacher role in user module: Disable the option to select the institution and manager of the user when creating the student.	Teacher

Corrections phase

Based on the initial prototype and the list of improvements as inputs, the correction phase is carried out in a unidirectional way in four activities adapted to this study (Amado-Salvatierra et al., 2015): (1) daily meetings: (2) reuse/adaptation of pre-existing material; (3) Development/ Modification; and iv) Software error testing.

As a result of this phase, the Final Prototype was obtained, shown in Figure 3, and accessible at the following link: https://github.com/luchV/PrototipoSofware.git.

Figure 3

Final prototype

Documentation Phase

The documentation phase is carried out in a unidirectional way in two activities (Amado-Salvatierra et al., 2015) adapted to the project: i) Preparation of the Data Dictionary and ii) Preparation of the User Manual. In this phase, the documentation that will allow us to understand the operation of the prototype is generated. As an output of this phase, the data dictionary and user manual were obtained (https://n9.cl/manual-de-usuario).

Implementation phase

The implementation phase is executed in a unidirectional way between three activities (Amado-Salvatierra et al., 2015): i) Perform software usability tests; ii) Organization technical support; and iii) Retrospective. This way, the prototype created in the Assembly and Development phase was tested in the field (Cheung, 2016). As a result of this phase, the final Prototype Usability report was obtained.

A survey was applied that was based on the System Usability Scale (SUS) (Bangor, 2009). Google Forms was used to extract the information using a 5-item Likert scale. In this case, the participants were 36 students from the Universidad del Azuay in the Educational Psychology career who carried out a representative sample of tasks for the product (usability tests) and then completed the survey before any discussion with the moderator.

The statistical analysis process was based on the work of (Cedillo Orellana, 2017) . The collected results validated the questionnaire through Cronbach's alpha, obtaining a value of 0.81. Since Cronbach's alpha was more significant than 0.7, it suggests that the questionnaire is valid and consistent in measuring the desired construct.

The usability measurement scale (SUS) was used to obtain the descriptive statistics through the Excel 2019 software. The result was 85.6, so the prototype corresponds to the " excellent " category with high usability. (Bangor, 2009).

This application is a web platform that will be hosted on the servers of the Universidad del Azuay. It is important to note that access to the application is free for public and private institutions in Cuenca. In this way, we ensure the application is accessible and beneficial to a broad spectrum of users in the city's educational community.

Conclusions

To respond to the research question, which focuses on the skills considered in developing software for auditory stimulation, observing that, according to the literary review, a significant percentage of the articles (42%) focus on activities to stimulate auditory skills, such as detection, localization, discrimination, and auditive identification. Another 42% is related to activities that stimulate linguistic and extra-linguistic skills, such as attention, concentration, memory, behavior, and interpersonal relationships. In addition, 24% of the articles address the control and management of frustration and the teaching of vocal acoustics, among other aspects. Based on the literature review, these findings align with the listening skills proposed by Condemarin and provide valuable information for the development of auditory stimulation software.

The web application prototype to stimulate listening skills is beneficial for children with speech disorders and learning difficulties and typically developing children between 5 and 7 years of age. The application offers stimulation activities and immediate feedback to improve the ability to recognize, discriminate, and interpret auditory stimuli, which can help develop communication in children. In addition, this prototype has great potential to complement traditional therapies and expand therapists' ability to meet their patients' needs.

Unlike other auditory stimulation applications, the developed prototype stands out for its voice recognition feature, which provides notable benefits: i) Practice Pronunciation: Speech recognition helps users perfect their pronunciation of words and sounds, providing accurate and effective feedback; and ii) Interactive instructions: Especially in apps for children, interactive verbal instructions make activities more dynamic and personalized, allowing users to give voice commands and receive interactive responses.

The system evaluation results showed high user satisfaction and excellent efficiency in technical and interface terms. Users found the system extremely useful due to its ability to customize stimulation activities and quickly generate reports. In general, the prototype is believed

to improve the quality of speech and language therapy services thanks to the implementation of advanced technologies such as voice recognition.

This tool is intended to significantly improve listening comprehension in high school students, a crucial skill for linguistic learning and communication. It is adapting the activities proposed by Condemarín in areas such as auditory awareness (recognizing natural and human-produced sounds), auditory memory (repeating words and associating them with images, verifying animal sounds), auditory discrimination (differentiating animal sounds and environment), and the recognition of initial, incorrect, and final sounds in words. Importantly, consistently fostering these listening skills from an early age is essential for language development, knowledge acquisition, and academic success.

Limitations and future works

In this first stage, the application was used only by professors acting as testers. In the next stage of this research, we must include kids to evaluate their reactions to the solution.

Regarding security, the code does not incorporate significant security measures like data input validation or attack prevention. It is essential to implement adequate security measures, mainly if the code handles sensitive information or interacts with users. For example, it is recommended to use the functions and methods provided by the Yii software framework to manage sessions, as they ensure the security and integrity of the application. Furthermore, validating and filtering all data inputs is essential to preventing vulnerabilities such as SQL injection or cross-site scripting (XSS) attacks.

The implementation of future improvements in the auditory stimulation web application includes:

1. Advanced Hearing Evaluation: It seeks to incorporate more advanced hearing evaluations that allow users to measure their listening skills more accurately, including their ability to comprehend and answer oral questions.
2. Improvement in Voice Control: It is intended to improve voice control functionality, mainly aimed at users with hearing disabilities, to further facilitate navigation and interaction through more precise and varied voice commands.
3. Intelligent Adaptation: The application will focus on developing a more intelligent adaptation to users' verbal responses. This will allow the app to adjust activities and difficulty levels more precisely, providing a more personalized and practical learning experience based on user performance.

These enhancements are intended to enrich the user experience and maximize the benefits of auditory stimulation through technology and voice interaction.

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