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Achievement or exploration? Gameplay in deaf and hearing children

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Abstract

Serious video games offer significant potential for inclusive education and cognitive assessment, yet accessible design for deaf children remains limited. This study evaluates whether inclusive design strategies implemented in the serious game *Visor 2.0* provide equitable gameplay experiences between deaf and hearing children, analyzing their gameplay profiles using in-game behavioral analytics. A sample of 284 elementary school children (106 deaf, mean age = 10.3; 178 hearing, mean age = 8.19) participated in gameplay sessions across three cities. Gameplay telemetry was categorized into sub-strategies corresponding to Achiever and Explorer player types. ANCOVA controlling for age and independent samples *t*-tests were conducted to compare overall achievement and specific gameplay strategies between groups. No significant differences were found between deaf and hearing children in overall mission progress ($p = 0.547$), indicating an equal capacity to fulfill the main objectives of the game. Hearing children scored significantly higher in the overall Explorer profile ($p < 0.001$) and action variability (Strategy E1, $p < 0.001$). Conversely, deaf children scored higher in collecting all crystal types (Strategy E3, $p = 0.044$) and exhibited lower performance in zombie freezing (Strategy A2, $p < 0.001$). In conclusion, the inclusive design features successfully created equitable conditions for game completion regardless of hearing status. Furthermore, serious game analytics proved to be an effective tool for evaluating accessible educational technology.

Introduction

Serious video games are currently a topic of great interest, thanks to their benefits for learning in different areas of knowledge [1], [2] and in improving skills and changing behavior [3], [4]. This type of video games has also been used in clinical settings, such as neuropsychological assessment [5], [6], [7]. One of the application areas that has been explored to a lesser extent is inclusive education. It has been identified that this type of games can be designed considering particular characteristics of populations with differential conditions in cognitive and sensory terms. This possibility takes more strength when considering the characteristics of games as a desirable scenario that includes high interaction, the possibility of making decisions, high immersion, and approximation to real contexts through narratives [8], [9]. In this article we address the *gameplay* of a serious video game designed for deaf and hearing children.

Despite the growing interest in serious video games, inclusive design remains limited, particularly for populations with sensory disabilities such as deaf people. Although game design has advanced significantly in areas such as gameplay, graphics, and narrative development, accessibility has not progressed at the same pace. As a result, the inclusive dimension of serious game design continues to be largely overlooked [10], [11].

Traditional video games have already begun to incorporate accessibility elements, such as subtitles, color contrast options, or volume and sound adjustments. However, these advances, while useful, are not enough when it comes to creating learning or training experiences in serious games for people with sensory disabilities. For example, for blind people, the absence of visual representation requires the design of games that rely on sound and tactile feedback, in addition to rich auditory narratives [12], [13]. Although subtitles have been implemented in many video games for deaf people, this has been done usually without the support of other strategies that would address accessibility limitations from multiple angles [14]. This is important because, for deaf people, adding subtitles may not be enough, as many of them experience significant challenges in literacy and reading [15], [16], [17]. In a learning context, other channels of communication such as sign language or visual representations must also be included to convey information in an appropriate way. Some video game designs aim to visualise the soundscape, transforming in-game sounds into visual cues such as icons, colours, waves, directions and animations, so that deaf people can perceive information that is normally conveyed through audio [18], [19].

In response to the need for greater accessibility, various studies have incorporated inclusive design strategies into serious games. For instance, Perdi-Dogs [20] is a serious game that aims to educate deaf users in computational thinking, planning, and problem-solving. The authors note that the design prioritised visual, symbolic, and tactile elements, as well as vibrotactile and visual feedback, to avoid reliance on complex language. However, they acknowledge that the video game's effectiveness has not yet been empirically evaluated due to the small size of the testing group.

Another example is Sign-Lingo, which the authors describe as a serious video game designed to encourage parents to develop sign language skills with their deaf or hard of hearing children [21]. However, its reliance on Kinect technology restricts its accessibility and use in different environments and on different devices, and the game has not yet been tested in real-world settings to determine its definitive impact on language development.

Despite these advances, developing accessible serious video games still presents many challenges. According to Lesmes et al. [12] the main challenge is that developers of serious games are mostly not trained with the specific needs of deaf population. The inclusion of deaf people in the design and testing of serious games is rare, which contributes to the fact that these games are not truly accessible to all. In addition, the lack of clear regulations and universal standards in inclusive game design makes it difficult for companies and developers to prioritise accessibility from the initial creation phase. This challenge can be tackled by setting up multidisciplinary teams with professional experts in inclusion and accessibility for people with differential conditions.

The literature has also identified various general limitations associated with the use of serious video games. Bigdeli and Kaufman [22] report drawbacks related to the use of serious games in areas such as health, where: a) they can cause anxiety in some people, b) the decrease of aspects associated with the game, such as fun and motivation, due to the ‘serious’ characteristics of these, c) the lack of an adequate design and, d) the incompatibility between the game levels and the skills of the users. All these drawbacks, as a general rule, originate from an inappropriate game design that does not consider the specific characteristics of the user and the area of knowledge to be addressed.

These design challenges have been addressed by some authors who have proposed key milestones in video game development. Saeedi et al. [23] propose that four stages can be identified in the design of a video game based on the System Development Life Cycle. These are: Analysis, Design, Development and Evaluation. In the analysis stage, the purposes, requirements and content of the game are defined. In the second stage, important elements such as mechanics, characters, story and music are set. This moment is characterised by being iterative, due to the adjustments that the design will surely require to

improve the user experience. In the development stage the game is programmed and tested. Finally, the last step is to evaluate the game to verify its coherence with the established objectives. This development framework is essential for incorporating the characteristics of populations with sensory diversity. Its iterative and evaluative approach ensures accessibility and inclusive design in serious games, providing an optimal gaming experience.

When we talk about players with diverse hearing conditions, gameplay experience becomes a relevant object of study in terms of the need to know how they perceive, interact and experience the game [24], [25]. In this order of ideas, there are approaches that seek to address the design of educational technologies from an accessibility approach focused on the experience of the players from the interface to the instructional step-by-step that the person could follow [26].

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To address the gameplay experience, one of the most widely used frameworks are player taxonomies, as they allow delimiting game experiences based on what motivates players in terms of their general behaviors during gameplay [27], [28], [29], [30], [31]. These taxonomies provide structured approaches to understanding how players interact with game systems, environments, and other participants, offering valuable insights into engagement patterns and motivational orientations.

One of the most influential and widely used taxonomies is that proposed by Bartle [27], who categorized players using a Cartesian plane defined by two dichotomies: interaction versus action on the horizontal axis, and players versus the game world on the vertical axis. Based on this framework, four player types were identified: (a) killers, oriented toward acting upon other players; (b) socializers, focused on interacting with other players; (c) achievers, motivated by acting upon the game world to accomplish goals and progress; and (d) explorers, interested in interacting with the game world to discover its mechanics and structure [32]. This taxonomy has been widely used as a heuristic framework for analyzing gameplay experiences and understanding player behaviors across diverse game contexts [33], [34].

Building upon this foundational work, several more recent player motivation models have emerged. For instance, Yee [29], [35] developed a motivation-based model derived from large-scale empirical studies of massively multiplayer online game players. This model identifies three primary motivational components: achievement, social interaction, and immersion, each encompassing multiple subdimensions such as advancement, teamwork, discovery, and role-playing. Yee's model provides empirical evidence supporting the existence of distinct motivational orientations that influence gameplay behaviors.

Similarly, the BrainHex model proposed by Nacke et al. [30] introduced a neurobiologically informed typology consisting of seven player types, including seeker, conqueror, daredevil, mastermind, survivor, socializer, and achiever. This model integrates affective and cognitive responses to gameplay experiences, linking player preferences to underlying emotional and neurobiological mechanisms, thereby offering a more granular perspective on player engagement.

In the context of gamification, Marczewski [31] and Tondello et al. [36] developed the Hexad User Types model, which categorizes users into six types: achiever, socializer, free spirit, philanthropist, player, and disruptor. This model extends earlier typologies by incorporating intrinsic and extrinsic motivational dimensions, particularly relevant in educational and gamified environments.

Despite these advancements, Bartle's taxonomy remains particularly suitable for educational research due to its conceptual clarity, parsimony, and enduring theoretical relevance. Notably, several subsequent models retain constructs conceptually aligned with Bartle's original categories, such as achievement-oriented, socially oriented, and exploration-oriented behaviors [29], [30], [31]. This continuity suggests that Bartle's taxonomy captures fundamental behavioral orientations that persist across different types of games and contexts.

Furthermore, its simplicity facilitates practical application in educational settings, where the goal is often to interpret observable player behaviors and engagement patterns rather than to conduct detailed psychological profiling. For this reason, Bartle's taxonomy provides an appropriate and theoretically grounded framework for analyzing player behaviors and interpreting gameplay experiences.

This study aims to evaluate the gaming experience using objective measures collected directly from players' actions throughout the game. We aim to determine whether there are differences in gameplay between groups of deaf and hearing children. This will enable us to analyse the effectiveness of the inclusive design strategies employed.

Method

Participants

The sample for this study comprised 284 children randomly selected in their educational institutions, from 3 different cities. All the children were in elementary school. The exclusion criteria were any diagnosis of neurological or developmental syndrome, according to the records of the schools. The sample was formed by a group of deaf children (n = 106; female = 42) with an average age of 10.3 (SD = 2.34) and a group of hearing children (n = 178; female = 88) with an average age of 8.19 (SD = 1.59). These differences in age between groups are significant (Welch t = 8,27; p = < 0.001). A higher mean age in deaf children is usual because of their late access to formal education, which is common in deaf children in Latin American populations (Díaz et al., 2021).

Instruments: Visor 2.0 is a serious game featuring a psychometric embedded test designed to assess executive functions and oriented to peace education. As a serious game, it is designed for peace education, besides its neuropsychological purpose (i.e. cognitive evaluation). It is an open world game, in which players must collect a certain number of crystals, of different shapes and colors, to open a portal where they find the last challenge (puzzle) of each level. In his journey through the scenario the player must deal with hordes of zombies for which he has different possibilities such as: annihilation, freezing or escape. Additionally, the player can interact with puzzles and villagers scattered throughout the scenarios.

For this study we selected a set of scores with the purpose of estimating two gameplay profiles (see Table 1). That is, *achiever* and *explorer*. This taxonomy follows the conceptualization of Bartle (1996). The included scores were:

- Max. Mission: Highest level the player has reached in the game (1–6)
- Achievement: This is a global score that registers different milestones in the game progression.
- Frozen zombie: The player shoots a zombie, freezing it for a short time.
- Zombies killed: The player shoots a frozen zombie, disintegrating it.
- Target crystals: The number of crystals collected corresponding to the stage's mission.
- Non-target crystals: The number of crystals collected that do not correspond to the stage's mission.
- Health-packs: Throughout the level, there are health packs that restore some amount of life bar. This score records the number of health packs used.
- Response to villagers: The player may encounter villagers in various locations throughout the stage. When passing nearby, the NPC's will initiate an interaction. This indicator records the number of times the player responds to that interaction.
- Actions: This metric tracks every action performed by the player (for example, shooting, picking up crystals, or talking to a villager). Temporary events, steps (movement), and events generated by the game are excluded from this score.
- Variability: This score tracks the number of different actions performed by the player. One point is awarded for each new type of action.
- Maximum number of pursuers: When the player enters the adversaries' detection range, the adversaries begin to pursue the player until they leave the detection range. If multiple adversaries are activated while others are still in pursuit, this indicator records the maximum number of pursuers activated simultaneously.
- Evasion: This records the number of times the player leaves the adversaries' detection range, thereby stopping the pursuit.
- Engaging puzzles: Throughout the level, the player may encounter puzzles. To solve them, the player must stand on the puzzle and press a specific key. When this happens, the minigame begins. This indicator records the number of puzzles the player has attempted.

Based on the above-described indicators, we identified clusters that provide information on various gameplay strategies. We identified four possible strategies for the achiever profile and three for the explorer profile (see Table 1). In all cases, these strategies comprise clusters of scores recorded during gameplay, as previously described.

Table 1
Scores for Gameplay Profile.

Player Type	Strategy	Gameplay Elements
Achiever	Strategy A1	Kill zombies; collect health packs; target crystals
	Strategy A2	Freeze zombies; target crystals
	Strategy A3	Response to villagers (low); puzzles engaging (low)
	Strategy A4	Efficiency: low time / high mission score
Explorer	Strategy E1	High variability; high number of actions; maximum number of pursuers
	Strategy E2	Evading zombies; response to villagers (high); puzzles engaging (high)
	Strategy E3	Target and non-target crystals

Procedure

Data was collected directly at the children's schools. The sessions were conducted by a neuropsychologist with basic training in sign language, supported by a multimedia engineer and at least by one of the bilingual teachers of the institution. The application of the video game was carried out in groups of 8 children per session. Each child played three sessions of approximately 40 minutes, on different days, over the course of a week. All the children's parents as well as the educational institutions signed an informed consent form. All the children who participated in the study expressed their assent. The entire project was approved by the lead university of the research group.

Data analysis

First, we transform all the variables of the study in standardized *z* scores, and then in *T* scores (to avoid negative values) which give a score range from 20 to 80 (approx.), and a mean around 50. These scores were added together to give a total score for each gameplay profile (i.e. 'Achiever' and 'Explorer'). Second, we contrast the groups (deaf/hearing) regarding the performance on the video game main mission, using a *t* test for independent samples. Third, we contrast all the scores of the gameplay profile between groups (deaf / hearing). To do that, and taking into account the significant differences in *age* between deaf and hearing children, we performed a series of ANCOVA using the *age* as a control variable.

Results

First of all we test whether there were differences in the performance of the groups (Deaf vs Hearing) using the *achievement* score, which reflects the overall progress in the game. We found no differences between deaf (Mean = 49.8; SD = 10.7) and hearing (Mean = 50.5; SD = 9.74) (t = -0.603; p = 0.547) (See Fig. 2). This means that deaf and hearing children's groups have similar results in solving the main mission of the game.

When contrasting the groups' scores on the achiever global score, no significant differences were observed (F = 3.02; p = 0.083). In contrast, on the explorer global score, hearing children (Mean = 151; SD = 18.1) outperform deaf children (Mean = 149; SD = 20) and these differences are significant when controlling for age (F = 16.4; p < 0.001) (See Table 2). Next, we will break down these analyses and focus on the individual scores for each strategy.

Table 2
Gameplay profile contrast between deaf and hearing children

	Deaf		Hearing		Contrast (ANCOVA)	
	Mean	**SD**	**Mean**	**SD**	**F**	**p-value**
Achiever						
Strategy A1	50,6	8,4	49,8	6,25	2,05	0,153
Strategy A2	49,7	8,35	50,6	8,03	15,8	**< 0,001**
Strategy A3	49,6	5,99	50,2	6,25	1,033	0,31
Strategy A4	50,6	7,29	49,4	11,9	0,627	0,429
Total Achiever	201	21,4	200	22,8	3,02	0,083
Explorer						
Strategy E1	48,4	8,74	51,2	8,81	38	**< 0,001**
Strategy E2	50,1	5,42	50,2	6,01	0,529	0,468
Strategy E3	50,4	10,5	49,8	8,33	4,1	**0,044**
Total Explorer	149	20	151	18,1	16,4	**< 0,001**

Even though in the achiever total score no significant differences were observed (F = 3.02, p = 0.083), when contrasting the groups' scores on single indicators, significant differences were observed in strategy A2 (F = 15.8; p < 0.001). In this case deaf children (Med. = 49.7; SD = 8.35) performed less well than hearing children (Med. = 50.2; SD = 8.03). Regarding the actions, this means there was a difference in the number of frozen zombies and target crystals collected.

In the explorer total score, significant differences were observed between the groups. When going into the details of the different scores of the explorer profile, significant differences were observed in the strategy E1 (F = 38; p < 0.001), which points to variability and flexibility during the game. In this case, the group of hearing children (Med. = 51.2; SD = 8.81) obtained a higher average score than the deaf children (Med. = 48.4; SD = 8.74). The score of strategy E3 (collecting all kinds of crystals) also shows differences between deaf and hearing. In this case, however, the deaf children (Med. = 50.4; SD = 10.5) scored higher than the hearing children (Med. = 49.8; SD = 8.33).

Discussion

This article contrasts the gameplay strategies employed by deaf and hearing children. The aim is to evaluate the suitability of a serious game for deaf users. To achieve this, we used scores taken directly from the video game that provide information about the users' strategies and gaming profile. First, we discuss these strategies and gaming profile scores.

Designing serious, inclusive video games requires consideration of the specific characteristics of populations with different cognitive and sensory abilities [37]. In terms of using sign language to provide instructions and information, it is important to note that, although the video game includes subtitles, written language is often difficult for deaf children to learn, and they usually do not achieve the same level of reading fluency as hearing children of the same age [15]. Hearing is essential for decoding written words via the phonological pathway [38], and for obvious reasons this pathway is affected in deaf children, especially in those who do not use a hearing aid or cochlear implant. Therefore, visual feedback and sign language prompts are key to compensate for possible difficulties in the process of reading instructions.

All the missions and instructions for playing Visor 2.0 are presented in videos featuring a sign language interpreter who represents a character in the videogame, providing key information necessary to solve the game. This character offers indications on how to move around, collect objects, confront zombies, activate portals and use the backpack. In addition, the central story of the videogame is presented at the beginning through a cinematic in which this same character narrates the events in sign language.

Costello et al. [39] tested 11 different games for accessibility for deaf or hard of hearing players. They found that enemies tend to be more difficult for deaf or hard-of-hearing players to defeat. Generally, video games include auditory cues to alert the player to the presence of the enemy. In this case, deaf players need visual information to alert them. The problem is that sometimes there is no visual indication of what an enemy is about to do [39]. Visor 2.0 includes an active mini-map on the screen that shows the presence of zombies in the areas through which the player moves. This visual information of the enemies on the mini-map is the feedback that both hearing and deaf players receive, as to the presence of the adversaries. To avoid possible disadvantages in one of the groups, the game does not include auditory feedback to anticipate the encounter with the adversaries.

This visual feedback also includes other alerts such as flashes, and elements on the screen such as the life progress bar, the mini-map and an image showing the player how many correct gems he/she has collected. This information is easily identifiable on the screen and allows the children to monitor the

progress of their game. Given the absence of auditory information, we included a color (purple) as a referent associated with zombies. This color is used in different elements of the game, such as the life bar, the damage the child receives from a zombie, and the child's appearance when in zombie mode.

To address the purpose of this study, we group indicators (scores) into two profiles of players that are associated with certain game strategies: Achiever and explorer. The achiever is characterized by goal orientation and speed in completing missions. The explorer enjoys traversing scenarios, finding items to collect, and activating side quests [27], [40], [41].

As for the four achiever strategies, differences only appear in strategy 2. The most important element of that strategy is freezing the zombies, rather than annihilating them. This means that the hearing children employed more the strategy of freezing the opponents. Since there are no differences in the other strategies in this category, and no differences in overall performance, this could indicate that even so, the deaf children had a harder time regulating their interaction with the zombies. That is, this could be related to the effect of some neuropsychological processes such as inhibition, a weak aspect in the cognitive development of deaf children [42], [43], because killing the zombies is a strong stimulus. In almost every game (and movie) involving zombies, the purpose is to kill them all. Because Visor 2.0 was designed for peace education, the action of eliminating the adversaries is penalized (the life bar of the player decreases). That means the children need to be able to inhibit the aggressive impulse. According to our results, this inhibition was harder for the children.

In terms of exploration, the hearing group have higher scores on strategy 1 which involves more variability of actions, while the deaf have higher scores on strategy 3, which includes the “wrong” crystals. Again, this could be related to neuropsychological aspects. The greater variability in the hearing may indicate greater cognitive flexibility. In this regard Chu and Chen [44] found that cognitive flexibility in children with DHH is delayed compared to hearing children, which was consistent with previous studies [45], [46]. In the case of incorrect crystals, this could be an inhibition-related issue.

It is interesting to note that despite the differences observed in some specific strategies associated with inhibition and cognitive flexibility, deaf and hearing children showed similar performance in accomplishing the main objectives of the game. This finding is particularly relevant because the purpose of inclusive game design is not necessarily to eliminate all behavioral differences between groups, but rather to ensure that players can access, understand, and successfully engage with the experience regardless of their sensory condition.

The results suggest that the accessibility features incorporated into Visor 2.0—including sign language support, visual feedback systems, color-coded cues, and the removal of auditory feedbak—were effective in creating equivalent opportunities for participation and progression. Although deaf and hearing children occasionally adopted different gameplay strategies, these differences did not prevent either group from reaching the game's goals. In this sense, the accessibility mechanisms appear to have compensated for potential barriers that are commonly reported in digital games designed primarily for hearing users.

From an educational perspective, this finding has important implications. Serious games are increasingly used to promote learning, assessment, and behavioral change. However, if accessibility is not adequately considered, children with sensory disabilities may be excluded from these opportunities. Our results provide evidence that accessible design can support comparable gameplay experiences for deaf and hearing children, allowing both groups to benefit from the motivational, cognitive, and educational potential of serious games.

Rather than focusing exclusively on performance outcomes, these findings highlight the importance of ensuring equity of experience. When accessibility is integrated from the early stages of development, serious games can become environments in which deaf children participate under similar conditions to those of their hearing peers. This contributes not only to inclusion in digital environments but also to broader educational goals related to equal access to learning opportunities.

We can additionally highlight the use of serious games analytics as an interesting way to collect information about the way users interact with the video game [6], [7]. This involves recording information directly from gameplay and provides objective evidence about how different populations experience and navigate digital learning environments. Such approaches may be particularly valuable for evaluating whether accessibility strategies are effectively supporting equitable participation.

Limitations and Future Directions

This study presents several limitations that must be acknowledged. First, while the game Visor 2.0 incorporated multiple accessibility features, the study did not isolate which specific features (e.g., visual cues, sign language videos, color coding) had the greatest impact on player performance. Future research should implement controlled experiments that systematically manipulate individual accessibility elements to better understand their contribution to gameplay effectiveness.

Third, although we discuss the possible influence of executive functions such as inhibition and cognitive flexibility on gameplay strategies, these variables were not directly assessed through neuropsychological testing. Future studies should include standardized measures of executive functioning to strengthen the interpretation of behavioral differences observed in the game.

Finally, the gameplay context is limited to a specific genre and platform (action-adventure with exploration elements). Future research could explore whether similar patterns of inclusion and strategy emerge in different types of games (e.g., puzzle, strategy, or multiplayer cooperative games), and whether platform differences (PC, console, mobile) influence accessibility and engagement among deaf players.

Conclusions

This study contributes to the understanding of how deaf and hearing children engage with a serious video game designed according to inclusive design principles. The main finding is that both groups achieved comparable performance in completing the game's objectives, suggesting that the accessibility features implemented in Visor 2.0 were effective in supporting equitable participation. Although some differences were observed in specific gameplay strategies, these variations did not translate into disadvantages in overall performance or mission accomplishment.

These findings highlight the value of designing serious games that provide multiple pathways for interaction and progression. Features such as sign language guidance, visual alerts, color-coded feedback, and the elimination of auditory advantages allowed deaf children to access and navigate the game under conditions comparable to those of their hearing peers. This suggests that accessibility should not be understood merely as a set of accommodations, but as a design approach capable of promoting equivalent gameplay experiences for users with different sensory characteristics.

From an educational perspective, the results reinforce the importance of incorporating accessibility strategies into the development of serious games and digital learning environments. Ensuring that deaf children can participate in gameplay experiences similar to those of hearing children increases their opportunities to benefit from the motivational, cognitive, and educational potential of game-based learning.

Moreover, the use of serious game analytics provided detailed insights into player behavior, demonstrating the value of in-game behavioral data as a complement to traditional assessment methods. Beyond evaluating performance outcomes, gameplay analytics can offer objective evidence about the extent to which accessibility features support equitable participation. The integration of inclusive design and serious game analytics therefore represents a promising direction for future research and practice in educational technology, particularly in contexts involving learners with disabilities.

Declarations

Author Contribution

C.M. Data collection, manuscript writing and revision, statistical analysis and graphs.D.B. Manuscript writing and revision.A.H. Data collection, manuscript writing and revision.

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Data Availability

The research project from which the data in this study derive was funded by Minciencias (Ministry of Science, Technology and Innovation of Colombia). The data set used in this study is publicly available at: https://osf.io/3zxf7/overview?view_only=7c62f812e46d462383fb6534232e17e9

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Figures



Figure 1

Screenshot of the serious game Visor 2.0

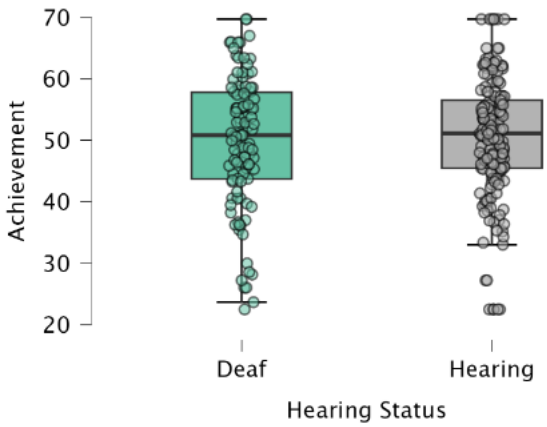


Figure 2

Distribution of Achievement scores split by hearing status