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## **Heuristic Evaluation of the Usability of the Autonomous System: An Assistive Technology for People with ALS**

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### **ORIGINAL ARTICLE**

**ABSTRACT:** This article presents a heuristic usability evaluation of the Autonomus System, an assistive technology developed by Technological Innovation Laboratory in Health (LAIS/UFRN) to support communication through eye blinking for people with Amyotrophic Lateral Sclerosis (ALS). The objective was to identify the system's strengths and weaknesses in order to propose improvements that increase its accessibility and effectiveness. The research was based on Nielsen's Heuristics, using a questionnaire administered to five expert evaluators. Data were analyzed using descriptive statistics (mean, standard deviation, range, variance, and confidence interval), complemented by classification of problem severity. The results indicated satisfactory performance, with emphasis on the visibility of system status and consistency of the interface, although aspects such as clarity of instructions, efficiency, and documentation require adjustments. The conclusion is that Autonomus represents a low-cost national solution with significant potential for social impact, but that it must evolve to fully meet the needs of users at different stages of the disease.

**Keywords:** Usability; Heuristic evaluation; Autonomus; Assistive technology; ALS.

# Avaliação Heurística da Usabilidade do Sistema Autonomus: Uma Tecnologia Assistiva para Pessoas com ELA

## RESUMO

Este artigo apresenta uma avaliação heurística da usabilidade do Sistema Autonomus, uma tecnologia assistiva desenvolvida pelo Laboratório de Inovação Tecnológica em Saúde (LAIS/UFRN) para apoiar a comunicação por meio do piscar de olhos para pessoas com Esclerose Lateral Amiotrófica (ELA). O objetivo foi identificar pontos fortes e fragilidades do sistema, a fim de propor melhorias que ampliem sua acessibilidade e eficácia. A pesquisa baseou-se nas Heurísticas de Nielsen, utilizando questionário aplicado a cinco avaliadores especialistas. Os dados foram analisados por meio de estatística descritiva (média, desvio padrão, amplitude, variância e intervalo de confiança), complementadas pela classificação da severidade dos problemas. Os resultados indicaram desempenho satisfatório, com destaque para a visibilidade do *status* do sistema e consistência da interface, embora aspectos como clareza das instruções, eficiência e documentação demandem ajustes. Conclui-se que o Autonomus representa uma solução nacional de baixo custo, com potencial significativo de impacto social, mas que deve evoluir para atender integralmente às necessidades de usuários em diferentes estágios da doença.

**Palavras-chave:** Usabilidade; Avaliação heurística; Autonomus; Tecnologia assistiva; ELA.

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## **1 INTRODUCTION**

Usability has become a central factor in the development of digital interfaces (1–3), especially in health-oriented systems, where user experience, ease of interaction, and efficiency directly influence both adherence and the effectiveness of interventions. The application of ergonomic principles, as pointed out (4), contributes to the safety, performance, and satisfaction of users, being crucial for the acceptance of tools in clinical and hospital environments. Among the various evaluation methods, Nielsen's Heuristics stand out for their effectiveness in identifying usability problems. Authors such as (2,5–7) reinforce that user-centered design should consider cognitive and emotional aspects of interaction, promoting the intuitive and efficient use of digital interfaces.

The Autonomus System (8) developed within the scope of the RevELA project (9) by the Laboratory of Technological Innovation in Health (LAIS/UFRN) in partnership with the Ministry of Health of Brazil, is a low-cost assistive technology (10–12) that enables communication for people with Amyotrophic Lateral Sclerosis (ALS) through blinking. It stands out as a national and free alternative to high-cost commercial solutions.

However, despite its relevance as a Brazilian technological innovation and its potential for social impact, there are no scientific studies that systematically evaluate its usability according to recognized criteria, a gap that limits the understanding of its potential impact and improvement. This study seeks to fill this gap by performing a heuristic evaluation of the Autonomus interface based on Nielsen's Heuristics, identifying strengths and weaknesses and proposing improvements. In this way, it contributes to the advancement of knowledge in usability applied to assistive technologies and strengthens the discussion on accessible and innovative solutions in digital health in Brazil.

This article is structured in five sections. The first is the introduction. The second presents the theoretical foundation regarding usability, Nielsen's heuristics, the Likert and Severity Scales, as well as conceptualizing ELA, describing the RevELA project and Autonomus. The third section details the methodology. The fourth presents the results and discussion of the heuristic evaluation, the classification of the severity of the problems found, and offers suggestions for improvement. Finally, the fifth section



presents the concluding remarks.

## **2 THEORETICAL FOUNDATION**

The theoretical foundation of this study addresses the concepts of Usability, Nielsen's Heuristics, evaluation scales (Likert and Severity), Amyotrophic Lateral Sclerosis (ALS), as well as the RevELA Project and the Autonomus System, the main focus of this investigation.

### **Usability**

Usability is a central attribute in the development of interactive systems, as it seeks to ensure that interfaces are clear, intuitive and efficient, facilitating the execution of tasks and providing a positive user experience (2,3). For Nielsen (13,14) usability represents the ease of use of a system, involving aspects such as speed of learning, efficiency, memorization, low error rate and satisfaction during interaction. In this sense, we have in (15) that usability should be considered not only as a technical requirement, but also as a determining factor for the adoption and success of digital technologies.

For (6) usability depends on the system's ability to allow the user to learn its functions, use them efficiently and remember them after periods of non-use, in addition to offering a satisfactory experience. To this end, they highlight principles such as consistency, immediate feedback and error prevention, which are fundamental to the design of user-centered interfaces. This aspect is especially relevant in health-oriented systems, where interaction failures can compromise not only the experience, but also the safety and well-being of the patient.

### **Nielsen's Heuristics**

Nielsen's Heuristics constitute a set of ten general principles for evaluating the usability of digital interfaces. Initially developed by Jakob Nielsen and Rolf Molich (16), these heuristics allow for the quick and efficient identification of design problems, even when applied by a small number of evaluators. The objectivity and simplicity of this method have made it widely recognized as a practical tool for usability diagnosis (17).

Nielsen's heuristics are widely recognized and validated as a heuristic evaluation method for web interfaces, their main characteristics are described by (15,18–20), based on publications from the Nielsen Norman Group (21). Among its principles, the following



stand out: visibility of system status, correspondence with the real world, user control and freedom, consistency and standards, error prevention, minimization of memory load, flexibility and efficiency of use, minimalist design, as well as help and documentation mechanisms (15,19,20). Due to its robustness and recognition, this model was adopted as a reference to carry out this evaluation of Autonomus.

### **Rating Scales: Likert and Severity**

The Likert scale (22) is widely used in social and psychological research to measure attitudes and perceptions through a set of statements evaluated on an ordinal scale. This technique allows the quantification of opinions and the statistical analysis of trends, becoming an effective tool for evaluating the usability perception of interactive systems. It allows capturing different degrees of agreement or disagreement, providing detailed quantitative data on respondents' experiences and opinions.

To complement this, Nielsen (23) introduced the Severity Scale as an instrument to classify the severity of usability problems. This metric considers the frequency of occurrence, the perceived impact, and the difficulty of overcoming the problem by the user, allowing for prioritization of the correction of critical flaws. By associating the scales, it becomes possible not only to identify problems, but also to measure their relevance to the user experience. While the Likert scale measures agreement or attitude, the severity scale focuses on the intensity of a phenomenon itself.

### **Amyotrophic Lateral Sclerosis**

The Amyotrophic Lateral Sclerosis (ALS) is a progressive neurodegenerative disease that affects upper and lower motor neurons (24,25) leading to muscle weakness, speech and swallowing difficulties, and respiratory failure in advanced stages (26). Average survival varies between three and five years after the onset of symptoms, although there are significant variations (24).

The diagnosis is predominantly clinical and supported by electrophysiological tests, such as electroneuromyography (27). Despite advances, there is still no known cure for ALS, which makes the use of assistive technologies essential to mitigate functional losses and enable a better quality of life. In this context, digital resources aimed at alternative communication have proven fundamental to ensuring the autonomy and social interaction of patients (28–30).

### **RevELA Project**



The RevELA Project (9) is a strategic initiative developed by LAIS/UFRN, in partnership with the Brazilian Ministry of Health (MS) and national and international collaborating institutions. Its main objective is to improve the quality of life of people diagnosed with ALS, through the development of technological solutions, professional training, formulation of clinical protocols and creation of a national patient registry (24).

The relevance of the RevELA Project lies not only in technological innovation, but also in its contribution to the promotion of social inclusion and health equity. By developing low-cost and free access solutions, such as Autonomus, the project differentiates itself from international commercial alternatives, which are often inaccessible due to their high cost, such as Tobii Dynavox® (31). In this sense, RevELA represents a milestone in the integration between science, technology and public policies, consolidating itself as a model of interdisciplinary initiative with a strong social and scientific impact (28,32).

### **Autonomus System**

Autonomus (8) is an assistive technology developed by LAIS/UFRN, within the scope of the RevELA Project (9) with the purpose of promoting communicational autonomy for people with ALS. It is free software that uses a common webcam to capture the user's blinking by eye tracking, transforming this movement into commands equivalent to mouse clicks (32,33). From this interaction, it accesses the system's functionalities, such as quick messages, sentence construction, writing and even a home automation module (Autonomus Smart Home) (30) for environments that meet the necessary prerequisites.

Assistive technology, according to the Brazilian Inclusion Law, number 13,146 of July 2015, is defined as a broad set of products, equipment, devices, resources, methodologies, strategies, practices and services that aim to promote functionality, related to the activity and participation of people with disabilities or reduced mobility, aiming at their autonomy, independence, quality of life and social inclusion (10–12). Assistive technologies (34) are crucial to promoting the inclusion and full participation of individuals with limitations in society, improving their quality of life and autonomy (12).

The conception of Autonomus (8) was motivated by the need to develop accessible alternatives to commercial assistive technologies such as Tobii Dynavox®,

which although effective, has a high cost, being inaccessible to a large part of the population (31,35). Digital solutions for alternative and augmentative communication play a fundamental role in maintaining the well-being and quality of life of people with ALS (28) and favor interaction with caregivers, family members and society, even in advanced stages of the disease. According to (24,28), assistive technologies should not only enable communication, but also promote digital and social inclusion.

Another distinguishing feature of Autonomus (8) is the fact that it is a constantly evolving technology that is made available free of charge and is open to participation by the user community. The system has a continuous improvement program, in which patients and caregivers can send suggestions, allowing the software to be updated collaboratively, increasing its effectiveness and suitability to real needs (8,9).

The Autonomus System Home Screen in operation is presented to demonstrate its interface and functionalities. In addition to the "I need help" function selected in Figure 01, we also have the options "Quick phrases", "My options" and "I want to write".

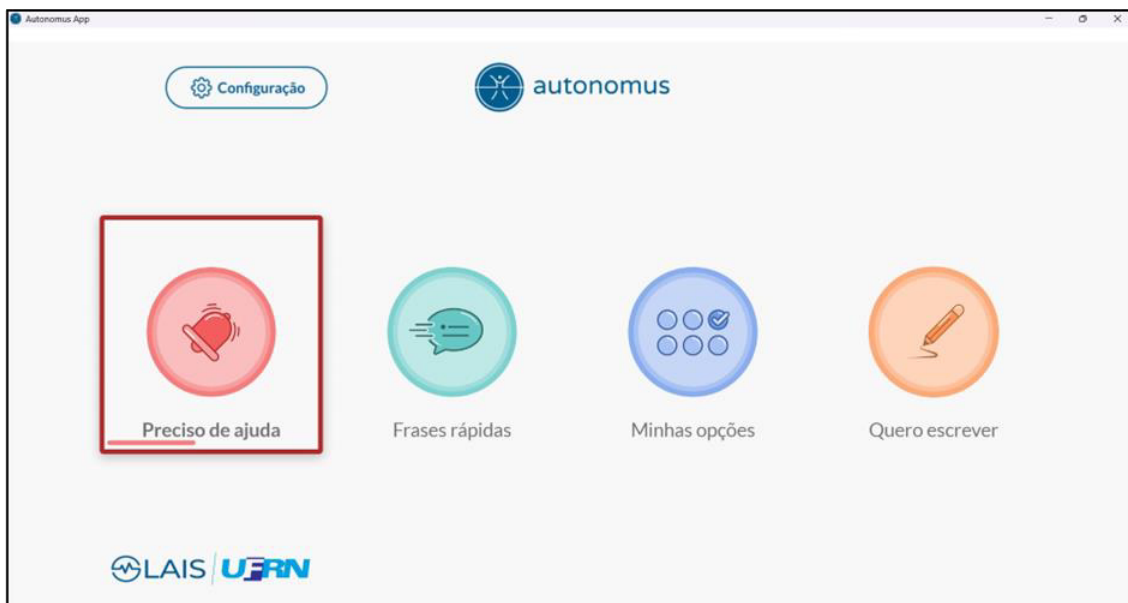


Figure 01 - Home screen of the Autonomus System (function "I need help" selected)  
Source: Adapted by the Author from the desktop program (2025)

### 3 METHODOLOGY

The methodology used in this study was designed to evaluate the usability of the Autonomus System using Nielsen's Heuristics. The process followed a descriptive approach, with steps organized to ensure consistency in data collection, analysis, and interpretation. The Figure 02 illustrates the methodology.

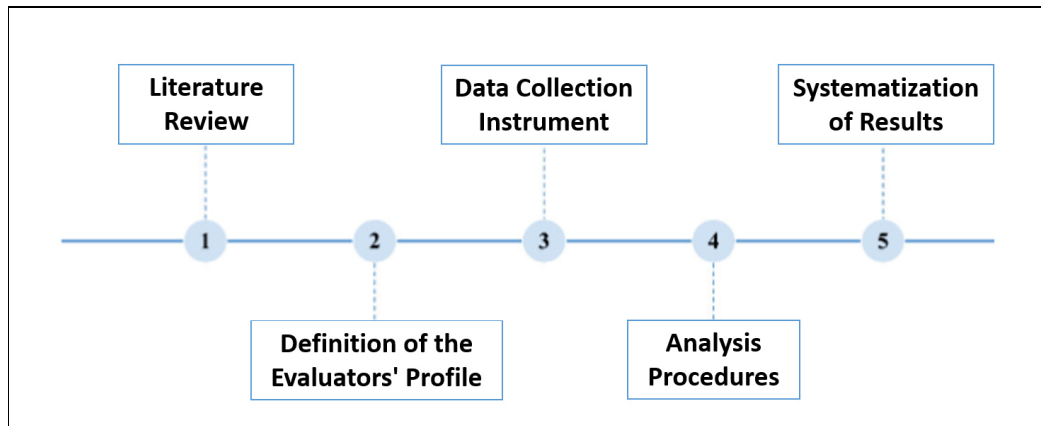


Figure 02 - Methodology adopted  
Source: The Author (2025)

Each step of the methodology illustrated in the previous figure will be detailed to explain how each step works.

### **Literature Review**

Initially, a literature review focused on the principles of usability and human-computer interaction was conducted, with emphasis on Nielsen's Heuristics. Specialized sources were consulted (2,15), including publications from the Nielsen Norman Group (19,21), recognized by international authority in the field of usability, as well as recent studies (18,36) and related works, (36–39) that applied heuristic evaluations in digital systems (20,40). This step grounded the choice of heuristic evaluation as an appropriate technique to identify usability problems in Autonomus, providing conceptual solidity to the study.

### **Definition of the Evaluators' Profile**

Five researchers participated in the heuristic evaluation, which, as recommended by Nielsen (41), is usually sufficient to identify most of the relevant usability problems in an interface. A perspective shared by institutions specializing in usability, such as the Interaction Design Foundation (42), which highlights that tests with small groups of users are more effective than applying a single test to a large sample.

The evaluators were professionals with prior knowledge of assistive technologies. This profile enabled a qualified analysis of the Autonomus System interface, both from a technical point of view and in its practical applicability for people with ALS. However, the composition of the sample did not directly include patients or caregivers, who are the end users of the system.

### **Data Collection Instrument**



For data collection, a structured questionnaire was developed based on Nielsen's ten Heuristics (15,20). The instrument included evaluative questions on a Likert scale (22), ranging from 1 to 5 points, in order to measure the degree of agreement of the participants in relation to aspects of the interface.

The Severity Scale (23) was used to classify the severity of the identified problems, considering criteria such as frequency of occurrence, perceived impact, and difficulty of overcoming. The questionnaire also included a space for qualitative comments, allowing evaluators to record observations and suggestions for improvement.

### **Analysis Procedures**

After data collection through the questionnaire, the responses of the five evaluators were categorized. This step sought to organize the findings systematically, using descriptive statistics (43–45) to identify usability patterns in the Autonomus System and to rank the problems according to their severity.

To perform the quantitative analysis, the simple arithmetic mean ( $\bar{x}$ ) of the responses assigned to each heuristic was initially calculated, according to the mathematical formula:

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n}$$

Where ( $x_i$ ) represents the value of each participant's response and ( $n$ ) represents the total number of evaluators.

The average makes it possible to obtain a central value that summarizes the participants' overall perception of each evaluated criterion: for the heuristics, averages between 4.1 and 5.0 indicate very positive evaluations; averages between 3.1 and 4.0, positive evaluations; averages between 2.1 and 3.0, neutral or negative evaluations; and averages between 1.0 and 2.0, negative evaluations.

For the Severity scale, averages between 4.1 and 5.0 are classified as highly critical problems, while values between 1.0 and 2.0 indicated low-impact failures. This systematization made it possible to identify strengths of the interface, as well as weaknesses that require adjustments.

The standard deviation (S) is used to measure the variability of responses around

the mean. This indicator provides information about the dispersion of the data, revealing whether the opinions of the evaluators were homogeneous or divergent. It is obtained using the formula:

$$s = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n - 1}}$$

Low standard deviation values indicate greater agreement among raters, while high values suggest discrepancies in usability perception. Additionally, the range (A) was considered, which corresponds to the difference between the highest and lowest values observed in the responses:

$$A = x_{m\acute{a}x} - x_{m\acute{i}n}$$

Calculating the range allows us to verify the total extent of the variation in responses, providing a direct indication of the heterogeneity in the evaluation of each heuristic or severity problem identified.

The results were interpreted in an integrated way, considering not only the average of the evaluations, but also the dispersion and the range. This approach allowed us to identify situations where high averages could hide relevant divergences between evaluators, in addition to facilitating the prioritization of improvements to Autonomus.

### **Systematization of Results**

The final stage of the methodology consisted of the systematic documentation and structured presentation of the results of the heuristic evaluation applied to the Autonomus System. The objective was to ensure the clarity, transparency, and reproducibility of the research, as well as to provide practical support for the improvement of the system.

Initially, the collected data were organized in spreadsheets to determine the values of mean, standard deviation, range, variance, and confidence interval (95%) (43,44), to present both the central tendency and the dispersion of the responses, allowing for a precise interpretation of the evaluators' perception in relation to each heuristic analyzed.

The results were divided into two blocks: the first focused on Nielsen's ten heuristics and the second on the classification of the severity of the identified problems, highlighting the heuristics that achieved the best scores, as well as those that registered



greater dispersion or lower mean.

This approach favored the prioritization of intervention, allowing the identification of which aspects should be addressed immediately and which can be the subject of gradual improvements. Similarly, the analysis of the severities helped in understanding the potential impact of the reported problems on the experience of using the system by people with ALS.

Finally, the actual results are found in the Results and Discussion section. This approach aims to ensure not only methodological robustness but also the practical usefulness of the study, with recommendations for improving the Autonomous System interface.

#### **4 RESULTS AND DISCUSSION**

The heuristic evaluation performed based on Nielsen's Heuristics allowed us to identify strengths and weaknesses in the Autonomous System interface. The results obtained are presented in Chart 1 and summarize the mean, standard deviation, range, variance, and confidence interval values for each heuristic evaluated.

Chart 1 – Results of the heuristic evaluation of the System

Heuristic Evaluation	Mean	Standard Deviation	Range	Variance	Confidence (95%)
H1 - Visibility of system status	4.8	0.40	1	0.16	0.35
H2 - Correspondence with the real world	4.2	0.75	2	0.56	0.66
H3 - User control and freedom	4.2	0.75	2	0.56	0.66
H4 - Consistency and standards	4.8	0.40	1	0.16	0.35
H5 - Error prevention	4.2	0.75	2	0.56	0.66
H6 - Recognition rather than recall	4.6	0.49	1	0.24	0.43
H7 - Efficiency and flexibility of use	3.8	0.40	1	0.16	0.35
H8 - Aesthetics and minimalist	4.6	0.49	1	0.24	0.43



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design					
H9 - Helps recognize and recover from errors	4.2	0.40	1	0.16	0.35
H10 - Help and documentation	3.6	0.49	1	0.24	0.43

Source: Research data (2025).

Overall, the Autonomus system shows positive performance. with averages above 4.0 in eight of the ten heuristics. Highlights included H1 – Visibility of system status and H4 – Consistency and patterns. both with an average of 4.8 and low dispersion (standard deviation of 0.40) and reduced amplitude with a value of 1. evidencing standardization and stability of responses. These results suggest that the interface provides clear information and maintains consistent interaction patterns. favoring the user experience. which is fundamental for users with ALS. We also have the heuristics H6 – Recognition rather than recall and H8 – Aesthetics and minimalist design. both with an average of 4.6. evidencing that the system presents a pleasant and intuitive interface.

The heuristics H2 – Matching the real world. H3 – User control and freedom. and H5 – Error prevention. presented averages of 4.2. but with greater variability (standard deviation of 0.75 and amplitude 2). This dispersion indicates divergences in the evaluators' perception. which may be related to a scarcity of clear error correction mechanisms and a lack of intuitive correspondence with already established interaction patterns.

However, two heuristics showed modest performance, indicating weakness. Heuristic H7 – Efficiency and flexibility of use, obtained an average of 3.8 (standard deviation of 0.40 and range of 1). This performance suggests that the system, although functional, has limitations regarding adaptation to different user profiles or usage conditions. In assistive technologies, flexibility is fundamental, since people with ALS may present different degrees of motor impairment, requiring highly adjustable interfaces.

Another point of attention was heuristic H10 – Help and documentation, with an average of 3.6 and a range of 1, as I obtained the lowest index of the entire evaluation. Even though this average is a positive evaluation, this result suggests a limitation in the informational support available to guide users, a critical aspect in assistive technologies

aimed at people with ALS who need clear and accessible resources to reduce communication barriers. These points may hinder the adoption of the system in a real-world use context, especially when the user depends entirely on the system for communication.

As an example of data collection, Figure 03 shows the result of heuristic H4 – Consistency and visual standardization of the system, with an average of 4.8, which is one of the highest averages in the heuristic evaluation.

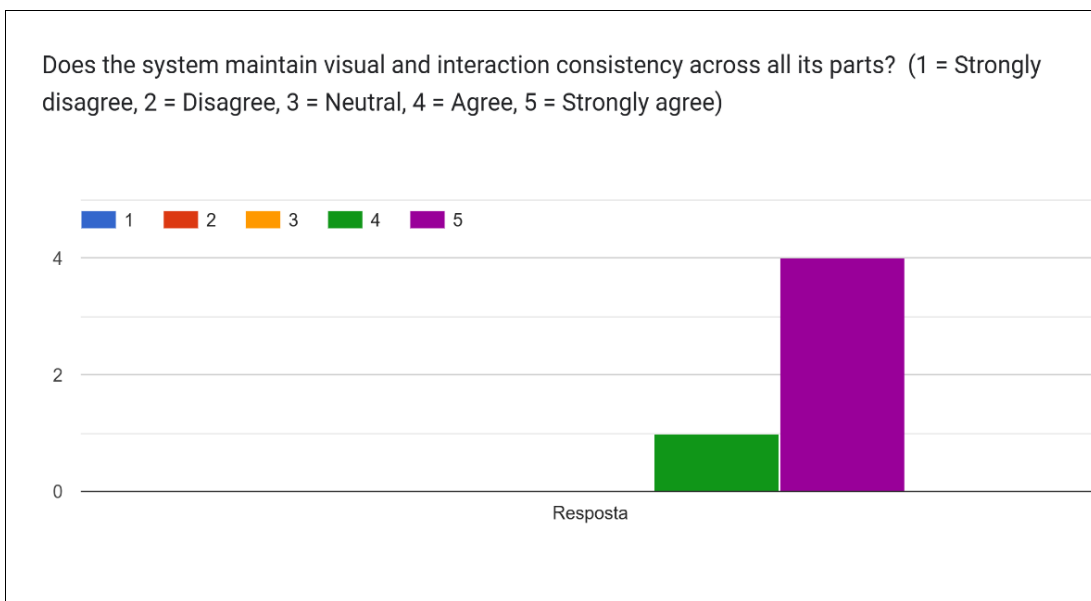
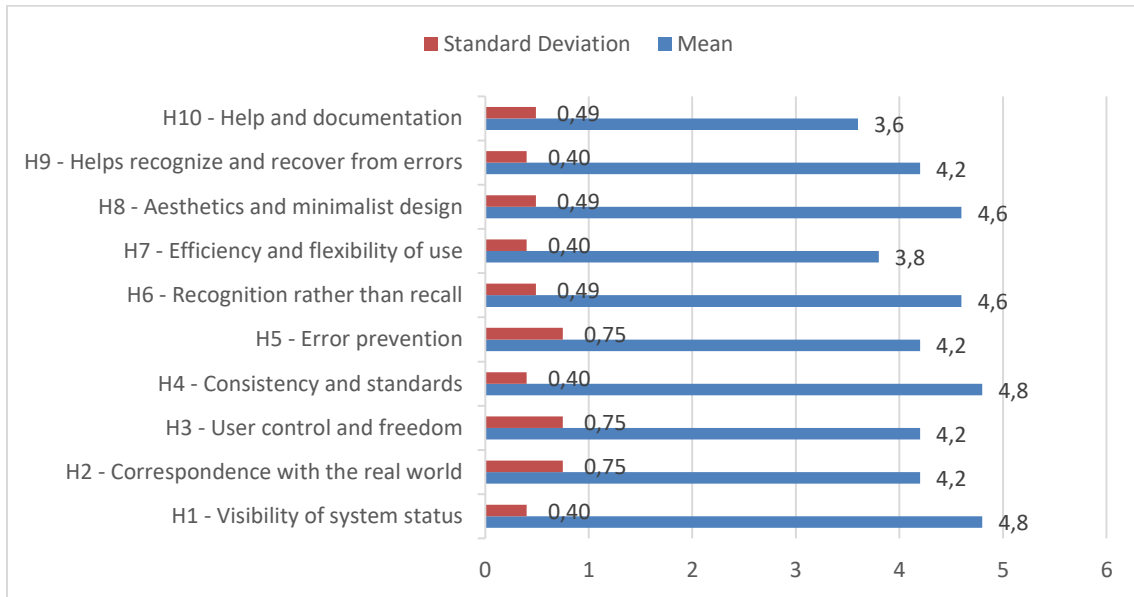


Figure 03 - Heuristic Evaluation - Autonomous [Heuristic 4]  
Source: Adapted by the Author via Google Forms (2025)

$$\bar{x} = \frac{5+5+5+5+4}{5} = \frac{24}{5} = 4.8$$

The Figure 04 summarizes the results obtained through the questionnaire and organizes the responses regarding the mean and standard deviation for each of Nielsen's ten Heuristics. The mean indicates the central tendency of the data, while the standard deviation shows the dispersion of the data around this mean (43,44).



**Figure 04 - Summary of the Results of the Responses to Nielsen's 10 Heuristics**  
Source: Data from research conducted by the Author (2025)

Regarding the classification of the severity of the problems, the results are presented in Chart 2.

Chart 2 – Classification of the severity of the problems identified in the System.

Classification of the Severity	Mean	Standard Deviation	Range	Variance	Confidence (95%)
S1 - General appearance of the screens	1.4	0.49	1	0.24	0.43
S2 - Clarity of instructions	2.0	0.63	2	0.40	0.55
S3 - Data entry	2.4	0.49	1	0.24	0.43

Source: Research data (2025).

The results of the Severity Classification indicate that the problems detected are of low to medium impact, not critically compromising the usability of the system.

S1 - General appearance of the screens, obtained the lowest average (1.4), suggesting only minor adjustments related to the layout.

S2 - Clarity of instructions, recorded an average of 2.0, with greater dispersion (standard deviation of 0.63 and range of 2), highlighting divergences between evaluators and indicating the need for greater standardization in support resources.

S3 Data entry, with an average of 2.4, showed consensus among evaluators regarding the importance of improvements, especially in contexts of advanced use of



the disease. Insufficient clarity of instructions (S2) and simplification of data entry (S3) are critical accessibility factors that can compromise the effectiveness of technology-mediated communication.

The confidence interval analysis (95%) reveals the statistical consistency of the results obtained. For the heuristics, the values ranged from 0.35 to 0.66, indicating relatively narrow margins, which reinforces the reliability of the calculated averages and suggests that the evaluators' perceptions tend to remain stable in similar applications of the instrument.

In the severities, the intervals ranged from 0.43 to 0.55, confirming the homogeneity of the responses and the robustness of the findings. Thus, although there are points to be improved in the interface and the clarity of the instructions, the results presented can be considered statistically consistent, giving greater validity to the interpretations about the usability of the system.

The integration between the results of the heuristics and the severity shows that Autonomus has a solid foundation of usability, especially in aspects related to the consistency and aesthetics of the interface, presenting itself as a viable low-cost national alternative to commercial solutions. However, improvements focused on documentation, clarity of instructions, and flexibility of use should be prioritized in order to broaden accessibility and ensure greater adoption by the target audience.

## **5 CONCLUSION**

This study evaluated the usability of the Autonomus System using Nielsen's heuristics, identifying strengths such as clarity in the visibility of the system status, interface consistency, and minimalist aesthetics, factors that contribute to an intuitive and accessible user experience. Although the system presents relevant strengths, the research also identified weaknesses related to the clarity of instructions, efficiency and flexibility of use, as well as documentation. The application of heuristic evaluation proved effective in revealing interface problems and guiding improvements, while the use of descriptive and inferential statistical measures contributed to a more consistent analysis, strengthening the validity and robustness of the results.

Despite the promising results, the restricted profile of the evaluators, composed



only of specialists, is recognized as a limitation. This characteristic, although it ensured technical rigor in the analysis, limits the generalization of the findings. It is recommended that future research include people with ALS and caregivers in the evaluation process, expanding the applicability of the results and the understanding of the system's use in real-world contexts.

In summary, the results indicate that the Autonomous System has the potential to be used as a low-cost national assistive technology for people with ALS, contributing to a fairer and more sustainable public health model. They also reinforce the importance of usability in the development of assistive technologies and highlight the strategic role of studies like this in guiding the incorporation of innovative, accessible, and socially relevant solutions into the Brazilian Unified Health System (SUS) by articulating science, innovation, and equity in access to digital health.

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