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UX/UI IN APPLICATIONS FOR PEOPLE WITH ASD BASED ON USER INTERPRETATION

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Abstract

This course completion work addressed the development of guidelines for IT professionals in creating computer applications aimed at children with ASD. The topic is relevant, considering the growing demand for accessible technologies that promote digital inclusion and meet the specificities of these personas. The general objective was to contribute to the development of more appropriate UX/UI, analyzing the perspective of proxy users, who represent the target audience. The methodology consisted of an ANACOR, involving the profile of personas with ASD and the elements of the application interfaces, with data collected through a survey applied to two proxy users. The main results showed patterns of association between the level of support needed for children with ASD and the interaction components of the interfaces, such as visual stimuli, frequency of use, level of attention, interaction with buttons/menus and sensitivity to sound. The general conclusion indicated that the proposed guidelines can help in the development of more inclusive and accessible applications, providing greater engagement and satisfaction for users with ASD.

Keywords: Autism; Human-computer interaction; Correspondence Analysis; Proxy User; Multimedia Elements.

Resumo

Este trabalho de conclusão de curso abordou o desenvolvimento de diretrizes para profissionais de TI na criação de aplicações computacionais voltados para crianças com TEA. O tema é relevante, considerando a crescente demanda por tecnologias acessíveis que promovam a inclusão digital e atendam às especificidades dessas personas. O objetivo geral foi contribuir para o desenvolvimento de UX/UI mais adequadas, analisando a perspectiva dos usuários proxy, que representam o público-alvo. A metodologia consistiu em uma ANACOR, envolvendo o perfil das personas com TEA e os elementos das interfaces das aplicações, com dados coletados por meio de um survey aplicado a duas usuárias proxy. Os principais resultados evidenciaram padrões de associação entre o nível de suporte necessário para as crianças com TEA e os componentes de interação das interfaces, como estímulos visuais, frequência de uso, grau de atenção, interação com botões/menus e sensibilidade ao som. A conclusão geral indicou

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que as diretrizes propostas podem auxiliar no desenvolvimento de aplicações mais inclusivos e acessíveis, proporcionando maior engajamento e satisfação dos usuários com TEA.

Palavras-chave: Autismo; Interação humano-computador; Análise de Correspondência; Usuário Proxy; Elementos Multimídia.

Introduction

Research on Autism Spectrum Disorder (ASD) has received continued attention, resulting in advances in both early and late diagnosis. Autism is a lifelong condition, and throughout life, the challenges and needs faced by individuals and their families can vary, depending on the individual's development, family circumstances, and available support. According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), individuals with ASD experience difficulties with communication and social interaction, as well as repetitive behavior patterns. ASD is categorized into three levels of support: Level 1 (requiring support), Level 2 (requiring substantial support), and Level 3 (requiring very substantial support). Despite this categorization, everyone has the right to adequate learning, especially in the school environment (Leite and Carmo, 2022).

According to the authors, historically, individuals with ASD have been excluded from mainstream education and often referred to specialized institutions. To guarantee the right to inclusive education, several legislative changes have been implemented. It is essential that the government encourage schools to train their teachers so they become professionals who can truly contribute to the education and well-being of students with ASD. Although some individuals show progress throughout their lives, this should not be seen as a reason to reduce access to interventions and services. Even with improvements, many still rely significantly on support from others in their daily activities.

The technological revolution in technology has brought significant improvements to the way people communicate, learn, work, and play. Tools like tablets and smartphones, like the iPad, have offered new features that facilitate communication and access to information. These advances have been particularly important for people with disabilities, who now have greater independence thanks to adapted applications such as screen readers and virtual assistants. This has profoundly transformed their interaction with the world, promoting greater inclusion and social integration, expanding their possibilities for communication and participation in society (Keefe-Cooperman, 2016).

Advances in technology and computing have yielded significant benefits, especially in the development of applications for children with ASD. The increase in the creation of these applications highlights the need for research into user interface (UI) design that meets the specific needs of these children. Because they are visual learners, children with autism show greater engagement in activities that involve visual interaction, facilitating their learning. Intuitive and accessible interfaces contribute to increasing these children's autonomy and making education more inclusive. By focusing on their cognitive needs and the development of social and communication skills, these interfaces can positively impact learning and

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development, providing tools tailored to their needs (Khowaja and Salim SS, 2015; Sofian et al., 2021).

In recent years, the principles of human-computer interaction (HCI) have become increasingly important in the creation of interactive systems for people with autism, as conventional usability standards do not adequately meet their needs. Applications require more specific guidelines due to their dynamic interfaces and unique characteristics. Designing a UI for autistic children involves additional challenges, such as creating accessible and intuitive visual environments. It is essential that these interfaces be designed based on appropriate principles, considering the social, cognitive, and communication difficulties and abilities of these children. The priority should be to develop tools that facilitate social interaction and enhance communication, using clear, visually appealing, and easy-to-navigate interfaces, promoting autonomy and effective use. (Punchoojit and Hongwarittorrn, 2017).

As identified in the state of the art, there is a gap in the guidelines for information technology (IT) professionals regarding the planning and implementation of hypermedia computing solutions adapted for people with ASD. Based on interactions with proxy users and children on the spectrum, the hypothesis emerged that the use of a dynamic UI, adjusted to the user's profile according to their level of support, could provide a superior user experience (UX) compared to static interfaces. This hypothesis can be evaluated through adapted UIs, developed based on user preferences collected through surveys and compared to a baseline found in the literature. This dynamic approach is expected to expand the resources available to IT professionals when creating solutions tailored to people with ASD, in addition to improving user engagement and satisfaction, enabling comparative analysis with traditional applications.

The main objective of this work was to contribute to the guidelines for IT professionals in the development of computer systems aimed at people with ASD, in addition to analyzing the UX/UI based on the perspective of the proxy user, promoting greater engagement and satisfaction of users with ASD, based on correspondence analyses between categorical variables involving the profile of the personas and the elements of the application interface.

Material and Methods

About the AEE school unit in the municipality of Barueri

This work was developed at a school unit [UE] located in the municipality of Barueri, which is part of the São Paulo Metropolitan Region [RMSP]. The institution serves elementary school students, covering both the early and late grades. In addition to regular classes, the school offers a Specialized Educational Assistance (AEE) center for students with special educational needs. This specialized service always takes place outside of regular classes, allowing students to receive individualized support for their specific needs. In addition to serving its own students, the UE also welcomes students from other schools in the region, promoting the inclusion of a diverse range of profiles, including students with ASD. Through the AEE, the school is committed to providing pedagogical strategies and resources that meet the needs of these

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students, contributing to their academic and social development in an adapted and inclusive educational environment.

The use of educational applications adapted for students with ASD is essential in the context of the school's Special Education Program (SEAP), as these tools help meet the specific learning needs of each student. Assistive technologies, such as alternative communication applications and educational games, are essential for facilitating social interaction and the development of cognitive skills. In this context, two SEAP teachers, who work directly with students and are referred to as proxy users, have in-depth knowledge of the specific needs of each of the 28 students diagnosed on the autism spectrum who are served in the morning and afternoon shifts. Based on their daily experience and practical experience, they are able to use these applications in a personalized way, adapting activities and technological applications to maximize student engagement and understanding. This strategic use of technology not only enriches the learning experience but also promotes social inclusion, helping students feel more integrated and confident in their abilities.

Exploratory review

The first stage of the study consisted of an exploratory literature review to identify the state of the art related to the proposed topic. For this purpose, the IEEE Xplore repository was used as the primary search source, due to its relevance and comprehensiveness in scientific publications in the areas of technology, engineering, and education. The search was conducted using specific keywords and combinations of terms related to the topic of interest, aiming to locate articles, conferences, and papers that discussed the most recent technologies, methodologies, and practices applied to the field under study. This survey allowed us to map the most relevant research, identify gaps in current knowledge, and theoretically support the project's development.

Data structuring and preprocessing

After this initial phase, a survey consisting of 10 multiple-choice questions was conducted using a Likert scale to assess various aspects related to the behavior and development of students with ASD. Responses were provided by the Special Education (SEA) teachers, who act as proxy users, as they have in-depth knowledge of the students' specific needs through daily interaction. The proxy users completed the questionnaire separately for each of the 28 students served, based on their regular and ongoing observations of the students' interactions and progress during classes and after-school activities using various selected technology applications. This process resulted in the generation of a database containing 28 observations, representing each student individually, and providing a detailed overview of the teachers' perceptions of the impact of UX/UI interventions and the behaviors displayed by students with ASD.

This study used qualitative data obtained through a survey that captured proxy users' perceptions of students with ASD. After data collection, data wrangling procedures were performed, including data extraction, processing, visualization, exploratory analysis, and

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modeling. Initially, these data were organized and manipulated in spreadsheets using Excel software, facilitating information structuring. Subsequently, the data were imported into Spyder IDE, version 5.4.3, an integrated development environment (IDE) for the Python language (version 3.11.7), where all advanced processing was conducted. Both native Python libraries and open-source libraries widely used in data science, such as Pandas, NumPy, Matplotlib, Seaborn, Scipy, Statsmodels, and Prince, were used to perform more robust and detailed analyses, ensuring appropriate processing and the generation of meaningful visualizations of the collected data.

Simple correspondence analysis

Correspondence analysis [CA] is a research technique used in various disciplines, such as engineering, psychology, and social sciences, among others. In social and behavioral fields, CA has established foundations and is widely applied to identify and interpret interactions between categorical variables. This method is frequently used to examine behaviors and relationships based on two or more variables that organize the objects of study on qualitative scales, which can be classified as nominal or ordinal. Thus, CA enables a deep understanding of how these variables relate, revealing important patterns and connections in the analyzed data (Khangar and Kamalja, 2017).

Broadly speaking, research typically classifies its observations, recording the number of occurrences for each variable analyzed. Beginning in the 1960s, there was a significant increase in the study of categorical data, the main purpose of which is to investigate the associations between variables in a given study or experiment. Several theories have been proposed over time, and CA has emerged as one of the most widely applied in various scientific fields. British mathematician Karl Pearson (1857-1936) developed statistical tools he called correlation, based on the work of Francis Galton (1822-1911). His contributions impacted fields such as psychology, anthropology, medicine, and sociology. Pearson was also responsible for the development of statistical tests such as regression and the chi-square test (SCHNEIDER, 2005). These methods served as the foundation for the creation of the CA technique (Fávero; Belfiore, 2015; Khangar; Kamalja, 2017).

In the 1960s, French mathematician and linguist Jean-Paul Benzécri made significant contributions by applying CA to case studies. Later, Jan de Leeuw and Chikio Hayashi also played important roles in advancing the field of CA. However, it was in 1984 that M. J. Greenacre, with the publication of his paper entitled *Theory and Applications of Correspondence Analysis*, popularized CA techniques globally. When it is necessary to examine categorical variables and understand the relationship between these variables and their categories, the exploratory technique called simple correspondence analysis (SCA) can be employed. This approach is applicable exclusively in situations where two categorical variables are the focus, limiting the study to the use of bivariate techniques (Fávero; Belfiore, 2015).

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ANACOR applies bivariate procedures to examine two categorical variables, their respective categories, and the strength of the relationships, using a contingency table or a cross-tabulation of classifications. The detailed mathematical foundation related to the development of ANACOR can be found in the work of Fávero and Belfiore (2015, p. 179-191).

In this study, the categorical variable referring to the level of support offered to children with ASD was always considered for the implementation of ANACOR. This variable was related to other variables, including visual stimulation, frequency of use, level of attention, interactivity with buttons and menus, and sensitivity to sounds, to verify the existence of associations between them.

Results And Discussion

Contingency Tables

Tables 1, 2, 3, 4 and 5 present the absolute frequencies observed between the categorical variables, always using the student's level of support with another categorical variable on a Likert scale, these are cross-tabulation tables.

Table 1: Analysis of the absolute frequency observed on the Visual Stimulus

Absolute frequency observed - Visual Stimulus

Support Level	High	Low	Medium	Total
Level 1	2	8	2	12
Level 2	3	1	9	13
Level 3	2	0	1	3
Total	7	9	12	28

Source: Original research results

Table 2: Analysis of the absolute frequency observed on the Frequency of Use

Absolute frequency observed - Frequency of Use

Support Level	Daily	Occasional	Weekly	Total
Level 1	9	0	3	12
Level 2	3	1	9	13
Level 3	2	0	1	3
Total	14	1	13	28

Source: Original research results

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Table 3: Analysis of the absolute frequency observed on the Degree of Attention

Absolute frequency observed - Degree of Attention

Support Level	High	Low	Medium	Total
Level 1	6	0	6	12
Level 2	0	2	11	13
Level 3	2	0	1	3
Total	8	2	18	28

Source: Original research results

Table 4: Analysis of the absolute frequency observed regarding Interaction with Buttons and Menu

Absolute frequency observed - Interaction with buttons and Menu

Support Level	High	Low	Moderate	Total
Level 1	7	0	5	12
Level 2	0	2	11	13
Level 3	1	1	1	3
Total	8	3	17	28

Source: Original research results

Table 5: Analysis of the absolute frequency observed on Sensitivity to Sound

Observed Absolute Frequency - Sensitivity to Sound

Support Level	Calmed	Increased stress	Neutral	Total
Level 1	5	3	4	12
Leve 2	1	5	7	13
Level 3	2	1	0	3
Total	8	9	11	28

Source: Original research results

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Association between two categorical variables and between their categories: χ^2 test and residual analysis

Once the cross-tabulation tables containing the observed absolute frequencies are obtained, it is possible to obtain the tables of expected absolute frequencies, residues, χ^2 values, represented by eq. (1), (2) and (3) respectively, as presented by Fávero and Belfiore (2017):

$$Expected\ absolute\ frequency_{11} = \frac{(\Sigma_{L1}\ x\ \Sigma_{C1})}{N} \quad (1)$$

$$Residue_{11} = n_{11} - \frac{(\Sigma_{L1}\ x\ \Sigma_{C1})}{N} \quad (2)$$

$$\chi^2{}_{11} = \frac{(Residue_{11})^2}{(Expected\ absolute\ frequency_{11})} \quad (3)$$

Still based on the authors, the χ^2 values are intended to verify whether there is a statistically significant association between the variables (using the sum of the χ^2 values):

H0: The variables are randomly associated.

H1: The association between the variables is not random.

Given the significance level and the degrees of freedom, if the χ^2 statistic is greater than its critical value, there is a significant association between the two variables (H1). The degrees of freedom are represented by eq. (4):

$$Degrees\ of\ freedom = (I-1)\ x\ (J-1) \quad (4)$$

Therefore, for this work, it is equivalent to 4 degrees of freedom.

Table 6 shows the total χ^2 values (using the sum of the χ^2 values) and the p-value, which represents the value obtained by the χ^2 test:

Table 6: Total χ^2 values and χ^2 test (p-value)

total χ^2 and χ^2 test (p-value)						
		Visual Stimulus	Frequency of Use	Level of Attention	Menu Button Interaction	Sound Sensitivity
	X^2 total	14,36	7,46	11,14	12,75	6,57

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p-value	0,0062 3	0,1135	0,0251	0,0126	0,1605

Source: Original research results

Heatmaps

A more detailed investigation of the interactions between the two variables is necessary, focusing on their categories, using both standardized residuals and adjusted standardized residuals. While the χ^2 test allows us to verify whether the frequency distribution of the categories of one variable in relation to the categories of the other is desired or indicates a pattern of dependence, the analysis of the adjusted standardized residuals, as stated by Batista, Escuder, and Pereira (2004), reveals the particularities of each category of a variable, considering the excess or absence of occurrences in its combination with the categories of the other variable, as shown in eq. (5) and (6):

$$Standardized\ Residue = \frac{residue_{11}}{\sqrt{expected\ absolute\ frequency_{\ 11}}} \quad (5)$$

$$Ajusted\ Standardized\ Residual_{\ 11} = \frac{standardized\ residue_{\ 11}}{\sqrt{\left[\left(1-\frac{\sum_{C1}}{N}\right) x \left(1-\frac{\sum_{L1}}{N}\right)\right]}} \quad (6)$$

If the adjusted standardized residual value "in a given cell" is greater than 1.96, it indicates a significant association, at the 5% significance level, between the two interacting categories in the cell; if it is less than 1.96, there is no statistically significant association (1.96 is the critical value of the normal for the 5% significance level).

Figures 1, 2, 3, 4, and 5 present the heat maps obtained in this work.

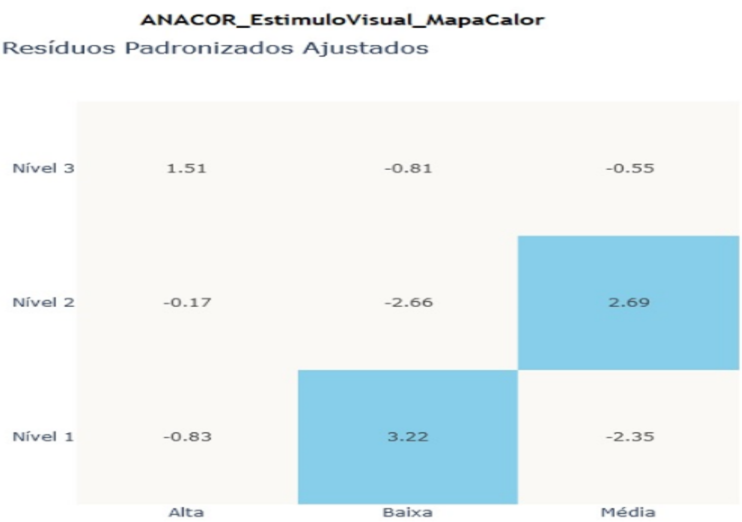

Figure 1: Heatmap - Support Level and Visual Stimulus

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Source: Original survey results

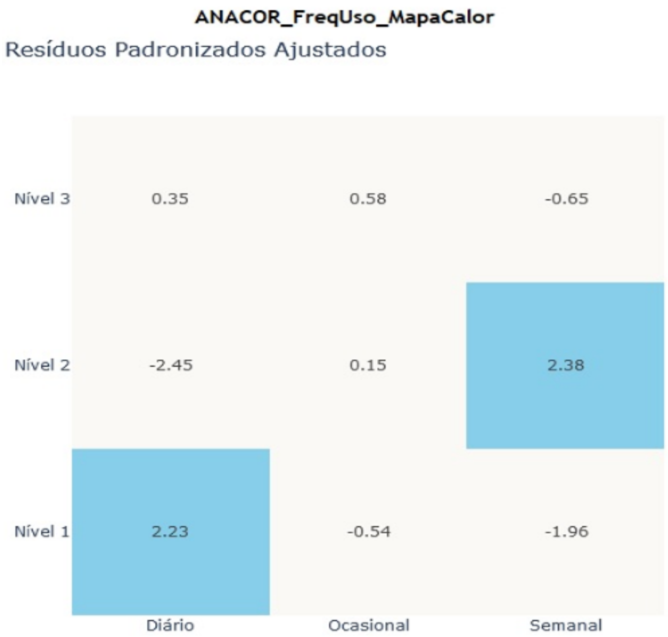

Figure 2: Heatmap - Support Level and Frequency of Use

Source: Original survey results

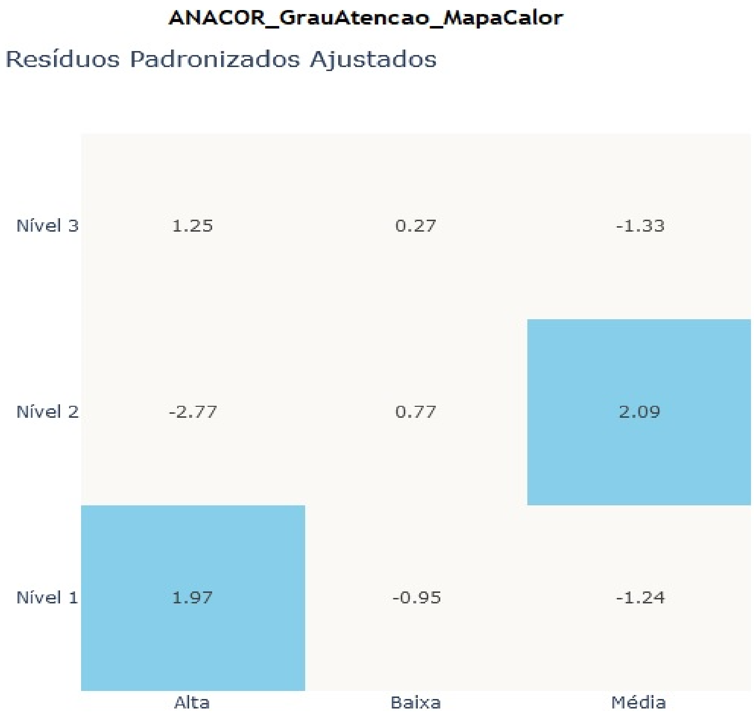

Figure 3: Heatmap - Support Level and Attention Level

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Source: Original survey results

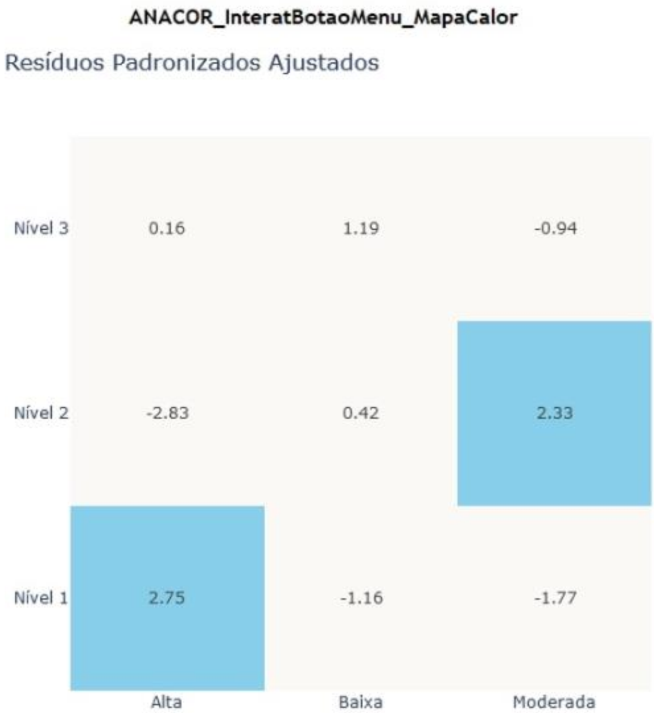

Figure 4: Heatmap - Support Level and Menu Button Interaction

Source: Original survey results

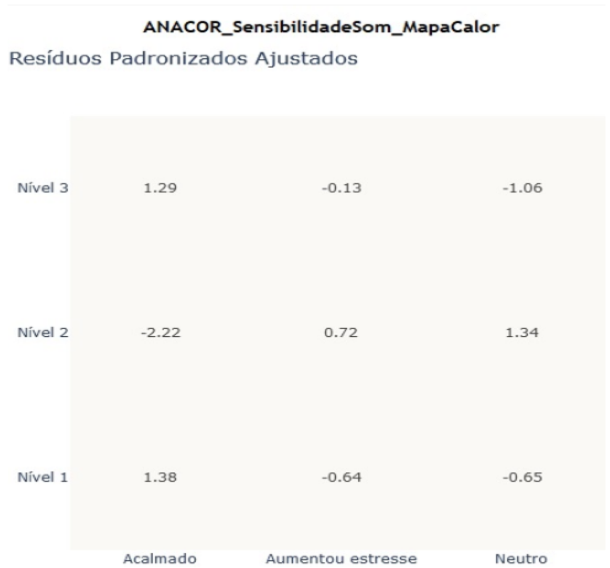

Figure 5: Heatmap - Support Level and Sound Sensitivity

Source: Original survey results

Inertial decomposition: determining eigenvalues

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It is worth noting that the χ^2 statistic tends to increase as the sample size (N) increases, which can compromise the assessment of the association between variables in contingency tables. To overcome this problem, according to Beh (2004), correspondence analysis uses the total principal inertia of a contingency table to represent the degree of relationship between two categorical variables, as expressed in eq. (7):

$$I_T = \frac{\chi^2}{N} \qquad (7)$$

The eigenvalue decomposition method is traditionally called the Eckart-Young method. This process generates m eigenvalues, where m = min(J - 1, J - 1). For example, if a given database provides a contingency table with dimensions of (3 x 3), m = 2 eigenvalues will be calculated. In correspondence analysis, these eigenvalues are also known as partial principal inertias (Fávero and Belfiore, 2017).

According to the authors, a matrix of proportions P, also known as the matrix of observed relative frequencies, can be defined, whose values are calculated based on the matrix X_0, as shown in eq. (8):

$$Matrix\ P_{11} = \frac{Standardized\ residue_{11}}{\sqrt{N}} \qquad (8)$$

Based on the matrix P, the matrix W is obtained: W = A' . A. Identifying W, the eigenvalues are obtained by solving the following expression: det(λ^2 . I -W) = 0. In matrix form, I can be represented by an identity matrix according to eq. (9):

$$\begin{matrix} \lambda^2 - w_{11} & -w_{12} & -w_{13} \\ -w_{21} & \lambda^2 - w_{22} & -w_{23} \\ -w_{31} & -w_{32} & \lambda^2 - w_{33} \end{matrix} = 0 \qquad (9)$$

Based on the eigenvalues (λ^2), the percentage of the total principal inertia of each dimension is found, as shown in eq. (10):

$$\begin{matrix} \%\ of\ Total\ Principal\ Inertia \\ (for\ each\ dimension) \end{matrix} = \frac{\lambda^2{}_{dimension}}{\lambda^2{}_{total}} \qquad (10)$$

The greater the total principal inertia (and χ^2), the stronger the association between the variables in the analysis, according to eq. (11):

$$Total\ Principal\ Inertia = \frac{\chi^2}{N} \qquad (11)$$

Tables (7), (8), (9), (10) and (11) show the two eigenvalues obtained respectively from the two dimensions (X, Y) referring to the contingency tables used in this work, also the sum of the 2 eigenvalues (total inertia), in addition to showing the proportion of each of the dimensions in relation to the total inertia (representing 100% of the inertia in the two dimensions).

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Table 7: Inertia - Visual Stimulus

Inertia - Level of Support and Visual Stimulus			
Dimension	Eigenvalue λ^2	% Inertia	Unique Value λ
1	0,419	81,68	0,647
2	0,094	18,32	0,307
Total	0,5130	100	

Source: Original survey results

Table 8: Inertia - Frequency of Use

Inertia - Support Level and Frequency of Use			
Dimension	Eigenvalue λ^2	% Inertia	Unique Value λ
1	0,266	99,85	0,516
2	0,00039	0,15	0,020
Total	0,2664	100	

Source: Original survey results

Table 9: Inertia - Degree of Attention

Inertia - Level of Support and Degree of Attention			
Dimension	Eigenvalue λ^2	% Inertia	Unique Value λ
1	0,395	99,25	0,628
2	0,003	0,75	0,055
Total	0,3980	100	

Source: Original survey results

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Table 10: Inertia - Button and Menu Interaction

Inertia - Support Level and Menu Button Interaction			
Dimension	Eigenvalue λ^2	% Inertia	Unique Value λ
1	0,382	83,96	0,618
2	0,073	16,04	0,270
Total	0,4550	100	

Source: Original survey results

Table 11: Inertia - Sound Sensitivity

Inertia - Sound Level and Sensitivity			
Dimension	Eigenvalue λ^2	% Inertia	Unique Value λ
1	0,225	95,74	0,474
2	0,010	4,26	0,100
Total	0,4550	100	

Source: Original survey results

Perceptual maps and observed coordinates

According to Beh (2004), decomposing inertia into a contingency table can be a useful tool for researchers to identify relevant sources of information capable of explaining the relationship between two categorical variables. As a result, this can facilitate the creation of perceptual maps. The most common method of decomposing inertia involves obtaining eigenvalues.

According to authors Fávero and Belfiore (2017), from the table of observed relative frequencies (matrix P), it is possible to introduce the concept of mass, which expresses a measure of importance or predominance of a category in relation to others, based on its recorded frequency. In this way, we can calculate the masses associated with the categories of the variable positioned in the rows and, similarly, the masses of the categories of the variable located in the columns of the contingency table, as shown in eq. (12) and (13):

$$Paste\ Line_{Category\ 1} = \frac{\Sigma_{L1}}{N} \tag{12}$$

$$Paste\ Column_{Category\ 1} = \frac{\Sigma_{C1}}{N} \tag{13}$$

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Below, Figure 6 presents the perceptual map and the observed coordinates obtained regarding Visual Stimulus.

ANACOR_EstimuloVisual_MapaPerceptual_CoordsObser

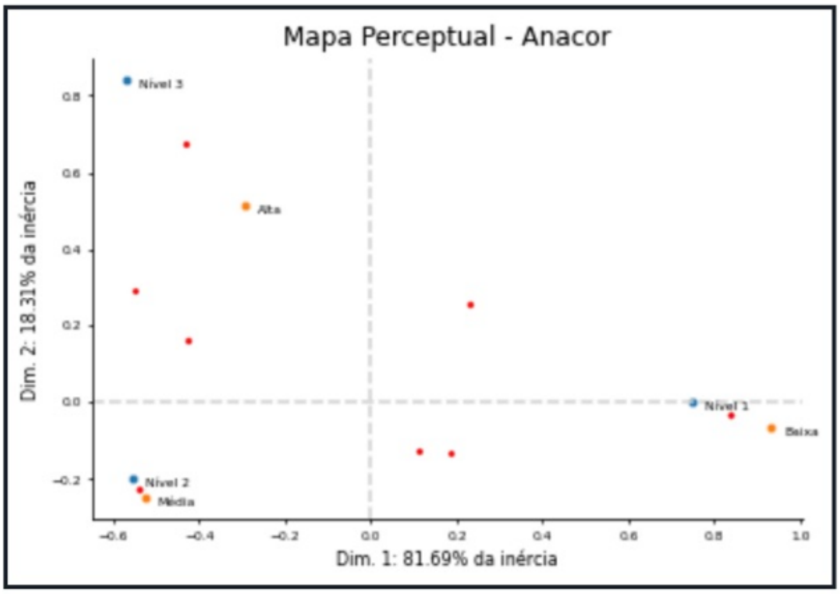

Figure 6: Perceptual Map and Observed Coordinates - Level of Support and Visual Stimulus Source: Original Research Results

Figure 7 presents the perceptual map and observed coordinates obtained regarding Frequency of Use.

ANACOR_FreqUso_MapaPerceptual_CoordsObser

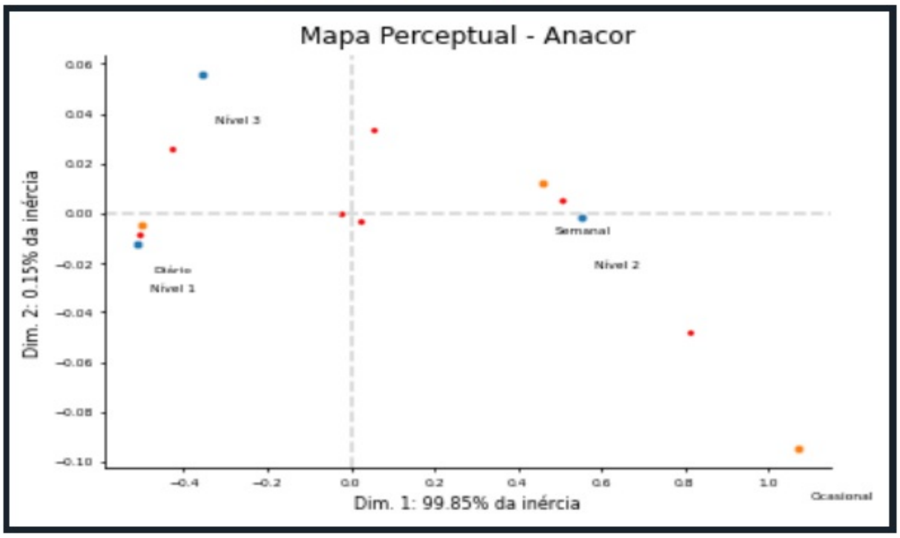

Figure 7: Perceptual Map and Observed Coordinates - Level of Support nd Frequency of Use

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Source: Original Research Results

Figure 8 shows the perceptual map and observed coordinates obtained for evel of Attention.

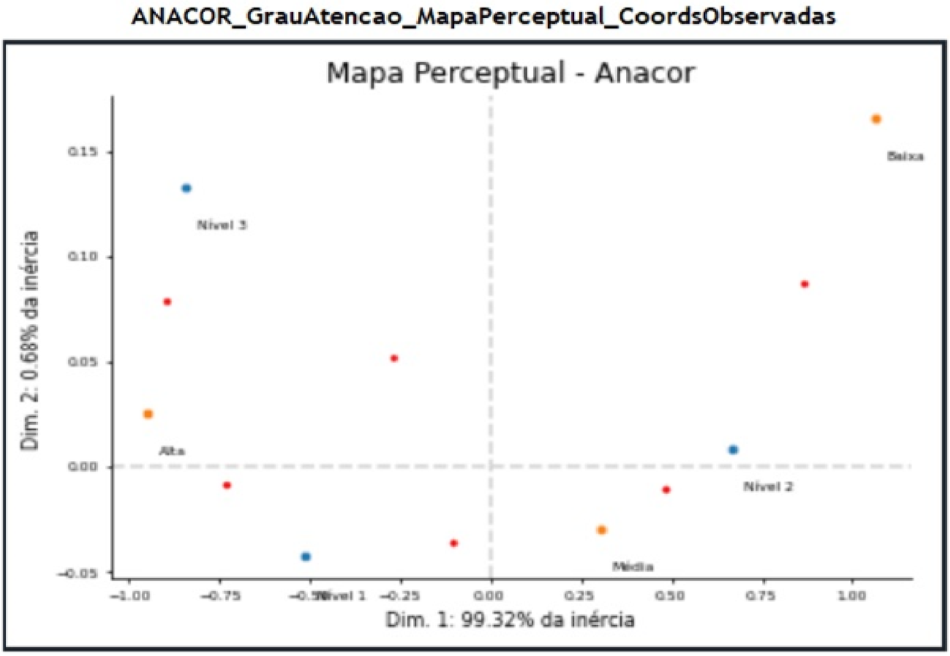

Figure 8: Perceptual Map and Observed Coordinates - Level of Support and Degree of Attention

Source: Original research results

Figure 9 presents the perceptual map and the observed coordinates obtained regarding the Menu Button Interaction.

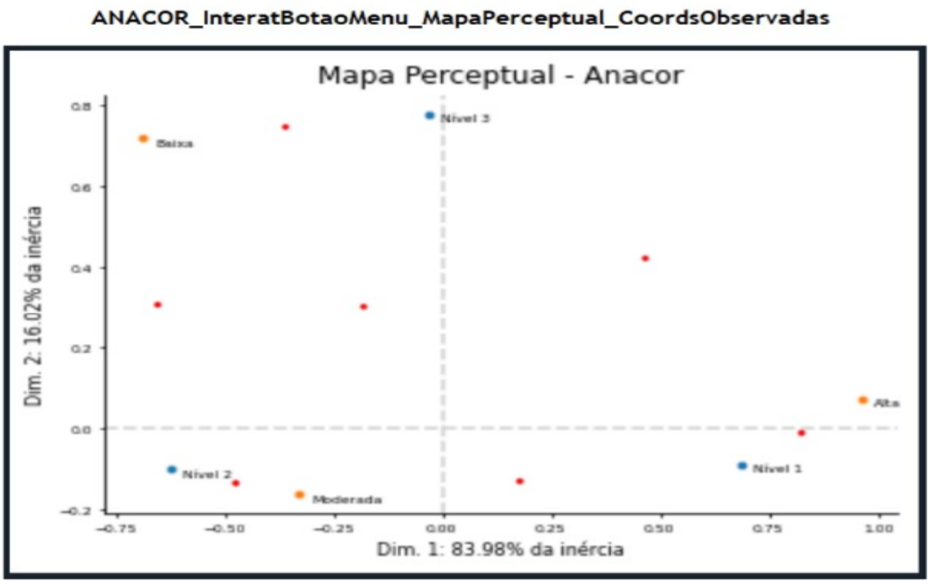

Figure 9: Perceptual Map and Observed Coordinates - Level of Support and Interaction Menu Button

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Source: Original Research Results

Figure 10 shows the perceptual map and observed coordinates obtained for Sound Sensitivity.

ANACOR_SensibilidadeSom_MapaPerceptual_CoordsObser

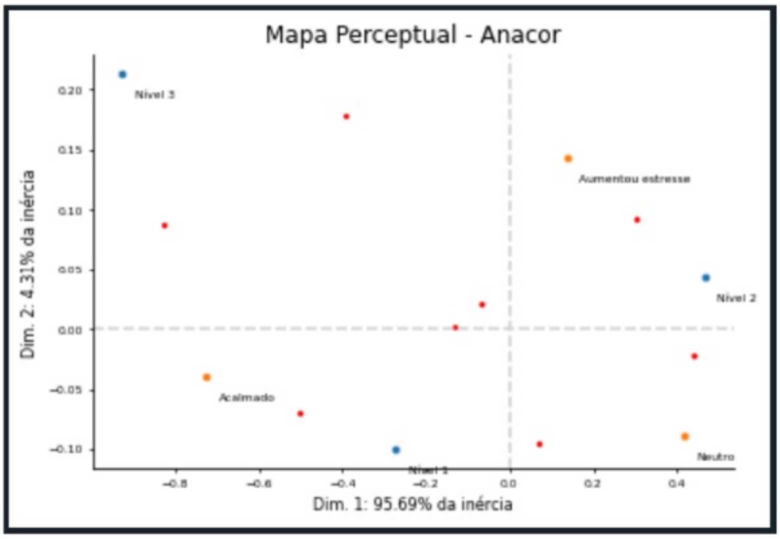

Figure 10: Perceptual Map and Observed Coordinates - Support Level and Sound Sensitivity

Source: Original research results

Final Considerations

The results obtained in this work presented guidelines that can assist IT professionals in the development of computer systems aimed at people with ASD, in addition to investigating the UX/UI from the perspective of the proxy user. Throughout the research, ANACOR (National Association of Autistic Spectrum Disorders) were conducted, considering the profile of personas with ASD and the application interface elements. The results highlight the importance of designing interfaces that not only meet the specific needs of these users but also promote greater engagement and satisfaction. The perspective of proxy users, who are familiar with the specificities and demands of individuals with ASD, proved essential for better understanding end-user interactions and preferences. The CAs conducted helped identify usage patterns and important associations between the users' support profile and visual stimuli, frequency of use, level of attention, button and menu interactions, and sound sensitivity, highlighting elements that can be optimized to improve HCI. Thus, this study contributes to the creation of more accessible, inclusive, and effective applications by aligning technology development with the behavioral and cognitive specificities of children with ASD. The proposed guidelines provide a starting point for developing solutions that are both functional and responsive to the needs of these users, fostering their digital inclusion.

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