NOVA SCHOOL OF
SCIENCE & TECHNOLOGY

DEPARTMENT OF
COMPUTER SCIENCE

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BSc in Computer Science

A CONCEPTUAL MODEL ON NEURODIVERGENT ISSUES IN SOFTWARE ENGINEERING

MASTER IN COMPUTER SCIENCE

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To my parents

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Abstract

Neurodiversity, a term used to describe a variety of neurological differences, such as autism, ADHD, and dyslexia, is gaining recognition and acceptance in society. In software engineering, neurodiversity can impact the design and development of software products, as well as the experiences and needs of users.

It is important to consider neurodiversity to create accessible and usable products that cater to the needs of a diverse user base. Despite the increasing interest in neurodivergent inclusive software, there is still a lack of consensus and understanding of what this means and involves. More research to understand how to create software that is accessible to neurodivergent individuals is needed.

We developed a conceptual model defining neurodivergent concepts and relationships that must be considered during the process of software requirements elicitation. This model was evaluated with the aid of a survey and finally we built a supporting tool for requirements elicitation based on the model defined.

The model was evaluated with 100 participants, 37 of which were Neurodivergent, and the results are promising.

Keywords: neurodivergent issues, neurodivergent accessible, requirements engineering, software engineering

Resumo

A neurodiversidade, um termo utilizado para descrever uma variedade de diferenças neurológicas, como o autismo, a ADHD e a dislexia, está a ganhar reconhecimento e aceitação na sociedade. Na engenharia de software, a neurodiversidade pode ter impacto na conceção e desenvolvimento de produtos de software, bem como nas experiências e necessidades dos utilizadores.

É importante ter em conta a neurodiversidade para criar produtos acessíveis e utilizáveis que satisfaçam as necessidades de uma base de utilizadores diversificada. Apesar do interesse crescente em software inclusivo neurodivergente, ainda há falta de consenso e de compreensão do que isto significa e envolve. É necessária mais investigação para compreender como criar software que seja acessível a indivíduos neurodivergentes.

Desenvolvemos um modelo concetual que define conceitos e relações neurodivergentes que devem ser considerados durante o processo de elicitação de requisitos de software. Este modelo foi avaliado com a ajuda de um inquérito e, finalmente, construímos uma ferramenta de apoio à elicitação de requisitos com base no modelo definido.

O modelo foi avaliado com 100 participantes, dos quais 37 eram neurodivergentes, e os resultados são promissores.

Palavras-chave: questões neurodivergentes, neurodivergente acessível, engenharia de requisitos, engenharia de software

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Acronyms

ADHD Attention Deficit and Hyperactivity Disorder *(pp. 1, 4, 6, 14, 18, 20, 22, 24, 29, 32, 34–37, 40, 43, 48–51, 53–57, 59–71, 74, 78, 80, 83–85, 90)*

ASD Autism Spectrum Disorder *(pp. 1, 2, 4, 5, 14, 16–19, 21–23, 25–28, 32, 34, 38–40, 43, 46, 48–51, 53–55, 59–66, 68–71, 73, 78, 80, 83–85, 90)*

AUIs Adaptive User Interfaces *(pp. 17, 19, 25, 33, 37, 39)*

SLR Systematic Literature Review *(pp. 2–4, 9–12, 26, 28, 29, 90)*

VR Virtual Reality *(pp. 16, 17, 19, 28, 29, 33, 38, 85)*

VUMS Virtual User Modeling and Simulation Standardisation *(pp. 18, 25)*

1

Introduction

The present dissertation aims to contribute to the inclusion and recognition of neurodivergent individuals during Software requirements elicitation by developing a conceptual model for neurodivergent concepts and relationships associated with issues when using software. Although the field of technology is always advancing, there is still a big gap regarding the inclusion of Neurodivergents in the software scheme. The model we developed supports the requirements engineering task of requirements elicitation, so that neurodivergent struggles can be considered more easily during software development. This initial chapter presents an overview of the context and motivation behind the research, as well as a better definition of the purpose and contribution of the dissertation.

1.1 Context

Neurodiversity, a term used to describe a variety of neurological differences, such as Autism Spectrum Disorder (ASD), Attention Deficit and Hyperactivity Disorder (ADHD), and Dyslexia, is increasingly gaining recognition and acceptance in today's society. Despite this progress, neurodivergent individuals continue to face numerous challenges in their daily lives, including difficulty in accessing appropriate education, employment, and health care. In recent years, there has been an increase in the prevalence of ASD [17]. The centers for disease control and prevention estimates that the rate of ASD in 2007 was between 55-57 per 10,000, a significant increase from the 1970s estimate of 20 per 10,000. This increase is likely correlated with the advancements in diagnosis and the increasing awareness.

In software engineering, neurodiversity can have a significant impact on the design and development of software products, as well as on the experiences and needs of users. During software development, it is important to consider neurodiversity to create accessible and usable products that cater to the needs of a diverse user base. For example, Avelar et al [5] have an interesting take on web accessibility and its meaning. They state that web accessibility implies that disabled people can use the Web effectively. According to their definition, this means the ability to effectively perceive, understand, navigate, and interact with the Web, contributing to its growth.

Software programs can be particularly beneficial to people with neurodivergencies such as ASD. Since constant changing or unfamiliar environments are particularly challenging to people with ASD, software programs can be beneficial as they provide a predictable and familiar environment [31]. Tasks can be easily repeated and software can provide consistent prompts and reinforcement. Software and technology are often delivered through a visual medium, such as desktop computers, which takes advantage of the strengths of the audience. Educational software can provide a one-on-one structured learning environment, often necessary for children with ASD to learn effectively. Software on technology devices may provide readily available and affordable teaching tools, addressing the shortage of instructors needed for intensive one-on-one teaching.

In summary, there is increasing interest in neurodivergent inclusive software, but given the lack of consensus and understanding of the field, more research is needed to help how to create software that is accessible for neurodivergent individuals.

1.2 Problem

The problem statement was identified based on a Systematic Literature Review (SLR) carried out and discussed in Chapter 3:

Lack of approaches on how to make Software accessible to Neurodivergent users

Although the topic is gaining more attraction, and more research is being carried out, there is still no consensus and understanding when it comes to neurodivergent inclusive software and what it means. Overall, there is not enough research trying to understand how to build neurodivergent-friendly software. Most of the existing studies focus on either a specific issue that they intend to solve or they broadly address the topic.

1.3 Purpose

The purpose of this dissertation is to develop a conceptual model for neurodivergent needs and concepts in software engineering. As a first step, we performed a state-of-the-art evaluation through a SLR, to discover both what initiatives and research have been carried out to address neurodivergent issues in software engineering, and the concepts that have been defined. This process is described in 3. With the results collected through this study we defined the main concepts and relationships and developed a Conceptual Model on Neurodivergent Issues and applied it to a use case scenario, as is described in 4. After the model was concluded, we carried out a survey of evaluation that validated the concepts and relationships included in the model. The survey gathered 100 participants and is reported in 5. Finally, we built a supporting tool for requirements elicitation that is summarized in 6.

1.4 Contributions

- An SLR about Neurodivergent Issues in Software Engineering;
- Analysis of the main concepts on Neurodivergent Issues and the relationships between those concepts;
- A Conceptual Model on Neurodivergent Issues in Software Engineering;
- A Survey evaluation of the model with 100 participants and application to a case study;
- A Supporting Tool to aid the use of the model.

1.5 Document Structure

The present document is structured into seven Chapters with the following content:

- Chapter 1 - Introduction: *This chapter introduces the context of the dissertation as well as the problem and purpose.*
- Chapter 2 - Background: *This chapter introduces the main concepts relevant to this dissertation such as neurodiversity, usability engineering and requirements engineering, and explains the methodology used for the state of the art review.*
- Chapter 3 - State of the Art: *This chapter reports the entire SLR process, from the Planning stage to the Results discussion.*
- Chapter 4 - A Conceptual Model on Neurodivergent Issues in Software Engineering: *This chapter presents the conceptual model along with the development process.*
- Chapter 5 - Conceptual Model Evaluation: *This chapter reports the survey conducted to evaluate the model and analyses and discusses the obtained results.*
- Chapter 6 - A Supporting Tool for Neurodivergent Accessible Requirements: *This chapter presents the prototype developed for the Supporting Tool to aid the interpretation of the model and support the requirements elicitation process.*
- Chapter 7 - Conclusions and Future Work: *This chapter discusses the conclusions and presents the planned future work.*

2

Background

This chapter aims to provide an overview of the neurodiversity issues we will approach, as well as the concepts of usability engineering and requirements engineering since our model is focused on software requirements related to software usability. Finally, we will explain the chosen research methodology of Systematic Literature Review (SLR).

2.1 Neurodiversity

In [3], the author describes neurodevelopmental disorders as a group of conditions onset during the developmental period, often before a child enters grade school. These disorders are characterized by developmental deficits that impair personal, social, academic, or occupational functioning. The range of deficits varies from specific learning limitations to global impairments of social skills or intelligence. Neurodevelopmental disorders often co-occur, such as Autism Spectrum Disorder (ASD) and Attention Deficit and Hyperactivity Disorder (ADHD). Clinical presentation includes symptoms of excess and deficits, with some disorders presenting with delays in achieving expected milestones. For instance, ASD is diagnosed when deficits in social communication are accompanied by repetitive behaviours, restricted interests, and insistence on sameness.

In [4], Austin et al. reference John Elder Robison, a scholar in residence and co-chair of the Neurodiversity Working Group at the College of William and Mary, that defines Neurodiversity as the belief that neurological differences like ASD and ADHD are due to natural genetic variation. Robison, who has Asperger's syndrome, adds that the concept of neurodiversity aims to demonstrate that people with differences need help and accommodation, not a cure.

According to [6], neurodiversity is a concept that challenges the traditional view of neurodevelopmental disorders as pathological conditions that need correction. The author emphasizes the importance of treating individuals with ASD with respect and dignity, rather than imposing strict treatment and normalization. This concept allows parents and adults the freedom to choose their interventions and promote their own potential. Neurodiversity is closely related to the concept of biodiversity, which emphasizes the importance of respecting the environment and its diverse life forms. It is seen as a step towards a more respectful way of thinking about our planet and communities, promoting a more inclusive approach to treatment.

Autism Spectrum Disorder According to [3], ASD is a condition characterized by persistent deficits in social communication and interaction, including social reciprocity, nonverbal communicative behaviours, and relationship skills. The diagnosis requires restricted, repetitive patterns of behaviour, interests, or activities. Symptoms change with development and may be masked by compensatory mechanisms. Therefore, the diagnostic criteria may be met based on historical information. Individual clinical characteristics are noted through specifiers, such as intellectual impairment, structural language impairment, associated with a known medical or genetic condition, or associated with another neurodevelopmental, mental, or behavioural disorder. These specifiers allow clinicians to individualize the diagnosis and provide a richer clinical description of the affected individuals. For example, many individuals previously diagnosed with Asperger's disorder would now receive a diagnosis of ASD without language or intellectual impairment.

Baron et al. in [7] states that ASD is a condition where individuals have a unique ability to recognize repeating patterns and become experts in "systemizing," which involves analyzing or constructing various types of systems. This ability is evident in their performance on tests like the physics test and the Systemizing Quotient, as well as in tests involving physical-causal concepts and mechanical systems. However, traditional IQ tests and exams may not accurately reflect their knowledge, and they may see information in terms of links, leading to a slow processing style. The strong systemizing in ASD is thought to be related to sensory hypersensitivity, with over 90% of children with ASD having sensory abnormalities. Studies have found superior low-level perceptual processing, such as more accurate detection of orientation and pitch processing in the auditory modality.

Dyslexia In [24] the author defines Dyslexia as a particular learning disability with a neurobiological basis. It is characterized by issues with precise and/or fluid word recognition, as well as by subpar spelling and decoding skills. Ineffective classroom instruction and a phonological deficit that is frequently unanticipated compared to other cognitive abilities are the usual causes of these difficulties. Secondary effects could include reading comprehension issues and a decrease in reading experience, which could hinder vocabulary and background knowledge acquisition.

[13] states Dyslexia is a language-based disorder affecting phonological processing, with ongoing research on its exact cause. Theories suggest it may be related to speech sounds and phonemic awareness impairment, but there is insufficient evidence to establish a causal link. Some theories suggest a generalized magnocellular system deficit, but this is challenged by sensory processing deficits in dyslexics. Dyslexics also have a wider visual perceptual mode, making reading difficult due to their inability to perceive individual

words without interference. Auditory processing deficits and attention deficits are also present. Recent research suggests auditory deficits may be similar to visual perceptual mode, and phoneme awareness improvement may result from multi-modal associations.

Attention- Deficit/Hyperactivity Disorder [38] characterizes ADHD as a neuropsychological disorder characterized by inattentiveness, impulsivity, and hyperactivity, which may also lead to exceptional creativity, particularly in divergent thinking. However, this advantage may be limited by the disorder's deficient inhibitory control, making it difficult to focus on tasks. While research suggests a correlation between divergent thinking and creative achievement in non-ADHD individuals, both divergent and convergent thinking are necessary for achievement. The impact of ADHD's divergent thinking on real-world creative achievement remains an empirical question requiring further research.

ADHD is the most common neurobehavioural disorder presenting for treatment in youth. ADHD is often chronic with prominent symptoms and impairment spanning into adulthood. ADHD is often associated with co-occurring anxiety, mood, and disruptive disorders, as well as substance abuse. The diagnosis of ADHD by careful review of symptoms and impairment is both reliable and valid. Recent genetic, imaging, neurochemistry, and neuropsychological data support the biological underpinning of the disorder. All aspects of an individual's life must be considered in the diagnosis and treatment of ADHD. Pharmacotherapy, including stimulants, antidepressants, and antihypertensives, plays a fundamental role in the management of ADHD across the lifespan. [39]

Wilens et al. in [39] state that in young people, ADHD is the most prevalent neurobehavioural condition that requires treatment. ADHD frequently has long-lasting effects that persist into adulthood, including co-occurring anxiety, mood, and disruptive disorders. It is valid and dependable to diagnose ADHD by carefully examining symptoms and impairment. Recent findings in neuropsychology, neurochemistry, imaging, and genetics support the disorder's biological basis. The diagnosis and treatment of ADHD must take into account every facet of the patient's life. To manage the symptoms, pharmacotherapy recommends stimulants, antidepressants, and antihypertensives.

2.2 Usability Engineering

Lawrence et all in [21] describe usability as the capacity to operate an interface and complete a task without realizing it. When users use an interface without realizing it and enjoying it, it is considered well-designed. When consumers feel irritated and the interface acts as a roadblock, impeding their progress, this is known as poor usability. Usability features are relevant to nearly everything, including websites and software. It is crucial to take into account general factors like ease of use, main activity slowdown, suitability for all users, and contribution of the usability approach to the main goal when assigning a usability rating or designing for good usability. The general characteristics of usability that apply to websites also apply to software.

According to [34], high-quality interface design is crucial for user experience and efficiency, and can be achieved through careful planning, consideration of user needs, thorough testing, and commitment to excellence. Managers can support this process by selecting the right personnel, establishing schedules, creating guidelines, and prioritizing testing. Successful designers understand the diverse user community and tasks involved and are dedicated to serving users despite challenges like tight deadlines and budgets.

Setting explicit goals based on system engineering and measurable human factors objectives is essential. Interfaces can enhance the quality of life and improve communities beyond functional purposes outlined in standards like the U.S. Military Standard for Human Engineering Design Criteria. Understanding user needs through requirements analysis helps avoid frustration with inadequate functionality or overwhelming them with excessive features. Ensuring reliability is essential to maintaining user trust and designers must prioritize privacy, security, and data integrity to protect against unauthorized access or tampering.

Designers aim for standardization, integration, consistency, and portability to enhance usability, reducing learning time and errors while minimizing disruption for users. Meeting project deadlines and budgets is critical, as delays or overruns can lead to market loss or customer resistance. Usability principles and rigorous testing reduce costs and development time, emphasizing the business value of superior interfaces.

Interface designers have a long history of documenting their insights and best practices in guidelines, establishing a shared language and promote consistency among designers in terminology, appearance, and action sequences. Designers engage in discussions about input/output formats, action sequences, terminology, and hardware devices during the creation of guidelines documents. Critics argue that guidelines can be too specific, incomplete, and difficult to apply, while proponents believe they contribute to steady improvements by building on the experience of design leaders.

2.3 Requirements Engineering

There are four fundamental software engineering activities: software specification, software development, software validation and software evolution [35]. In the software specification phase, the functionalities of the software and its qualities and constraints must be identified and defined. In software development, the software produced needs to meet the specifications. In software validation, the software must be validated to ensure that it does what the stakeholders want. Finally, in the software evolution phase, the software must be prone to evolve to meet the changing environment and customer needs.

According to [20], requirements are defined during the early stages of system development as a specification of what should be implemented. A requirement can be a description of how the system should behave, an application domain information, a constraint on the system's operation, or a specification of a system property or attribute. Requirements engineering is a term invented to cover all of the activities involved in discovering, documenting and maintaining a set of requirements for a computer-based system. Thus, the requirements engineering process includes requirements elicitation, requirements analysis and negotiation and requirements validation, as follows: [20]

1. **Requirements elicitation:** The system requirements are discovered through consultation with stakeholders, from system documents, domain knowledge and market studies.

2. **Requirements analysis and negotiation:** The requirements are analysed in detail and different stakeholders negotiate to decide which requirements are accepted. There is usually some flexibility in requirements and negotiation is necessary to decide on the set of agreed requirements for the system.

3. **Requirements documentation:** The agreed requirements are documented at an appropriate level of detail. In general, there needs to be a requirements document that is understandable by all system stakeholders.

4. **Requirements validation:** There should be a careful check of the requirements for consistency and completeness. This process is intended to detect problems in the requirements document before it is used as a basis for the system development.

There are four dimensions to requirements elicitation: application domain understanding, problem understanding, business understanding, and understanding the needs and constraints of system stakeholders [20]. Effective requirements elicitation is very important. If the customers' real requirements are not discovered, they are unlikely to be satisfied with the final system. Requirements elicitation and requirements analysis are closely linked together since as requirements are discovered during the elicitation process, some analysis is inevitably carried out and problems are recognised and discussed. A good requirements elicitation process should include the following four critical activities: [20]

1. **Objective setting:** The overall organisational objectives should be established at this stage. These include general goals of the business, an outline description of the problem to be solved and the constraints.

2. **Background knowledge acquisition:** The engineers gather and understand background information about the system, which includes information about the organisation where the system is to be installed, the application, and any existing systems to be replaced.

3. **Knowledge organisation:** Organise the knowledge collected in the previous stage. This involves identifying the system stakeholders and their roles in the organisation while prioritising the goals of the organisation.

4. **Stakeholder requirements collection:** This is the stage mostly known as elicitation. It involves consulting the system stakeholders to discover their requirements and deriving requirements from the application domain and the organisation.

Most of the knowledge in requirements elicitation comes from reading documents about the system and talking to the people who are involved with the system as users, managers, etc. Some of the most popular requirements elicitation techniques are interviews, scenarios, observations and social analysis [20].

In conclusion, requirements engineering has a critical role in ensuring the concepts os accessibility and usability are considered and integrated in the software development process by having a user centered approach and a requirements definition phase where accessibility and usability requirements can be listed.

2.4 Systematic Literature Review: A Process Summary

A SLR [19] is a method of evaluating and interpreting all available research relevant to a particular research question or topic. It is considered to be of higher scientific value when compared to a traditional, ad-hoc literature review because it follows a well-defined methodology, with a predefined search strategy, explicit inclusion and exclusion criteria, and documentation of the search process.

A SLR is performed in several discrete stages that are broadly agreed upon by the medical and sociological guidelines, broadly summarized into three main phases: Planning the Review, Conducting the Review, and Reporting the Review.

The Planning phase includes: identifying the need for a review, specifying the research question(s) and search string, developing a review protocol or selection criteria, and defining a quality assessment protocol.

The Conducting phase involves: identifying the relevant research, selecting primary studies, assessing the quality of the studies, extracting and monitoring the data, and synthesizing the data.

The Reporting phase includes: specifying dissemination mechanisms, formatting the main report, and (optionally) evaluating the report.

2.4.1 Planning Phase

Before conducting a systematic review, it is important to confirm the need for it and define the research question(s) the review will address.

The importance of specifying research questions in a systematic review cannot be understated. The research questions drive all aspects of the systematic review process, including the search process, data extraction process, and data analysis process. The critical aspect of a systematic review is asking the right question, one that is meaningful and important to practitioners and researchers, and leads to changes or increased value in current software engineering practice. The structure of a research question should consider the population, intervention, comparison, outcome, and context (PICOC) criteria. The population in software engineering experiments could be a specific software engineering role, a category of software engineering, an application area, or an industry group. The PICOC criteria help framing the research question in a way that allows for the identification of appropriate study designs and the selection of primary studies.

2.4.2 Conducting Phase

A search strategy must be determined and followed in consultation with experts and librarians. The research question is broken down into facets, and synonyms and alternative spellings are determined. Initial searches for primary studies can be done using digital libraries but other sources must also be searched manually.

The selection criteria for primary studies in software engineering research should be based on the research question and should be decided before conducting the study to reduce the likelihood of bias. The study selection process is multistage, starting with interpreting the selection criteria liberally and obtaining a full copy of the study if it can't be excluded based on the title and abstract. The next step is to apply inclusion/exclusion criteria based on language, journal, authors, setting, participants, research design, sampling method, and date of publication. The researchers may refine their exclusion criteria by considering questions not being addressed in their study.

The quality of primary studies is an important aspect to assess in a SLR. This quality refers to the degree to which the study minimizes bias and maximizes internal and external validity.

2.4.3 Reporting Stage

Finally, in the data extraction stage, the objective is to design data extraction forms for collecting information from primary studies in a systematic and unbiased manner. These forms should be designed to collect all necessary information to address the review research questions and study quality criteria. They should also be piloted to assess technical and usability issues. The data extraction forms should include standard information such as the reviewer's name, extraction date, publication details, and space for additional notes. Electronic forms can facilitate subsequent analysis.

The final stage in conducting a systematic review is writing the results and sharing them with relevant parties.

In conclusion, a SLR is a comprehensive evaluation of research on a specific topic that follows a defined methodology, with clear inclusion and exclusion criteria, and documents the search process. It provides a thorough overview of a phenomenon and can use meta-analytic techniques to increase the chances of finding real effects.

2.5 Summary

In this chapter, we introduced the main concepts needed throughout this dissertation. We first discussed what is Neurodiversity and the three conditions we will focus in this dissertation, afterwards we introduced the overview of usability and requirements engineering and finally we concluded with the methodology of SLR which we will be applying in the next chapter.

3

State of the Art

After the initial overview of the main concepts relevant to this dissertation shown in the previous chapter, the next step is to perform a state-of-the-art analysis through a SLR.

3.1 Methodology

Our goal is to understand what neurodivergent issues have been addressed in Software Engineering, and how they been addressed. That is, what guidelines, methodologies and tools have been created to support those issues in Software Engineering. Moreover, we intend to gather all the necessary information on every concept regarding this topic, and their relationships. To accomplish our goal, we carried out a SLR that consists of three main phases: planning, conducting and reporting [19]

3.1.1 Planning Stage

In the first step we formulate the research question and the search string, and then apply it to multiple digital library searches. We then define the search strategies, that is, which libraries to use as well as the search string and what information we are looking to extract from said resources that we will use when performing the search [19].

Research Question To define a search question, we conducted the PICOC analysis shown in Table 3.1.

Table 3.1: PICOC Analysis.

Population	Papers that address **neurodivergent issues** in **Software Engineering**.
Intervention	The neurodivergent issues in Software Engineering listed and their respective proposed intervention.

Comparison	Not applicable to this context. We intended to classify the approaches based on specific criteria and to collect concepts, not to compare them.
Outcome	An analysis of the issues neurodivergents face in software engineering, with the respective concepts and solutions.
Context	Preparation phase of the computer science masters thesis.

This led to the following research question definition, and related sub-questions:
RQ: *Which issues do neurodivergent people face in Software Engineering?*
Q1: *What neurodivergent issues have been recognised?*
Q2: *What approaches have been set to address those issues in Software Engineering?*
Q3: *Which guidelines have been concluded to solve those issues?*
Q4: *Which areas have those guidelines covered?*
Q5: *What concepts have been defined?*

3.1.2 Search String

The keywords of the research questions and their related words led to the construction of the final search query string, as described in Table 3.2. Each row will then be connected with an AND operator.

Table 3.2: Research query building.

Research question	Which issues do neurodivergent people face in Software Engineering?
Neurodivergent	(neurodivergent OR autism OR adhd OR asperger OR dyslexia OR asd)
Software Engineering	("software engineering" OR "software modeling" OR "requirements engineering")

We used Google Scholar, and IEEEXplore to perform a testing search. The results obtained were very small in size, an average of 25 papers per website without any selection or elimination. So we decided to broaden the search string to include "software", "information technology", "autistic" and "dyslexic". The expression "Software Modeling" also was converted to "Software Model" for a broader scope of results. The final research query is the following:

Table 3.3: Final research query.

Research question	Which issues do neurodivergent people face in Software Engineering?
Neurodivergent	(neurodivergent OR autism OR autistic OR adhd OR asperger OR dyslexia OR dyslexic)
Software Engineering	("software engineering" OR "software model" OR "requirements engineering" OR "software" OR "information technology")

3.1.3 Selection Criteria

We executed the search string on the Google Scholar and IEEExplore libraries and decided to include as well: B-On, Scopus, and Web of Science. Afterwards, it was necessary to determine the inclusion and exclusion criteria. During the first iteration each paper was evaluated considering its title, abstract, and keywords following a specific set of rules. Only papers that met the SC1 criteria and at least one more of the following selection criteria would be included:

SC1: *Written in English*

SC2: *Talks about ASD, Dyslexia, ADHD, Aspergers or Neurodivergency in relation to Software*

SC3: *Talks about one of the conditions mentioned above in relation to Software Design*

SC4: *Answers to the research question or at least one of the research sub-questions*

On the other hand, the paper would be excluded if it met one of the following exclusion criteria

EC1: *Is not written in English*

EC2: *Is not relevant to the research question or sub-questions*

EC3: *Is educational or diagnosis software for children*

EC4: *Is a duplicate*

Quality Assessment

Unfortunately, due to the few number of articles returned with the search string, we decided to only apply a quality assessment to the conference papers encountered. The CORE score and the overall credibility of the font was taken into account, when selecting the papers.

3.1.4 Conducting Stage

We applied the search string on multiple databases (see Table 3.4). We acessed that B-On, Scopus and Google Scholar included papers from the other libraries so we decided to start from with the B-On results as they seemed the most accurate for our research.B-On is an official database that contains sources from multiple other websites (such as IEEE and Scopus), we first started by analysing those results, so if later on some duplicates might occur we could identify them quickly. In every database we made used of the advanced research feature to apply the search string on the title and proceeded by filtering the results to written in English and full text available.

Table 3.4 summarises the results of the search. The first column corresponds to the libraries selected after the basic filters, the second shows the number of results after applying a database search and the third column refers to the papers extracted after the selecting process described above. The "Manual Search" row refers to papers found by either citations found on papers already selected or suggested by the respective supervisors. Even though we executed the search string on multiple digital libraries, the ones used during the selection processes were B-On and Scopus as both databases included papers from other digital libraries and we concluded them to be the ones with the best and most relevant results after a general analysis on the remaining libraries and concluding most did not apply to any inclusion criteria. As such, the other libraries also contain not applied (N/A) in the selected studies column. The number of papers excluded from each exclusion criteria applied is shown by Table 3.5.

Table 3.4: Conducting stage results.

Source	Potential Studies	Selected Studies
Google Scholar	347	N/A
B-On	269	9
Scopus	99	2
Manual Search	7	7
Total	722	18

Table 3.5: Exclusion Criteria.

Exclusion Criteria	Number of Excluded	Percentage
EC1	2	0.65
EC2	96	31.37
EC3	131	43.81
EC4	74	24.18

3.1.5 Reporting Stage

In this section, we discuss the results obtained after reading all papers selected in the previous stage and extracting the information which was registered in the extraction form.

Q1 - What neurodivergent issues have been recognised?

In total we found 7 papers ([27], [31], [28], [2], [18], [12], [33]) that answered this question. We will present a summary of the data extracted from each paper related to the question Q1.

In [27], the authors claim that software applications made for users with ASD in mind might only be usable by a few due to the condition's complexity and diverse characteristics. Thus, it is necessary to consider ASD users' different possible characteristics. Meanwhile, [31] tackles the fact that while many researchers report on successful software/technology-based products and prototypes, very little is known about how well, or if, these solutions are currently integrated into the lives of the targeted users, and thus explored different evaluation methods.

In [28], the authors claim that autistic users have other characteristics that must be considered in the software to be developed, for example, verifying whether the user is verbal or non-verbal, whether it is of high or low functioning, age, among other aspects. These characteristics and limitations are, most of the time, not known to the software development team. However, both in the literature and in the professional market, it is not easy to find techniques for surveying software requirements for this audience. Many works describe elicitation techniques only conceptually, such as the interview technique. Their motivation was to generate guidance for inexperienced designers/ developers for dealing with requirements elicitation in the ASD context.

According to [2], who implemented a Virtual Reality (VR) software to aid individuals with ASD with job interviews, existing VR interview simulations are largely limited in the degree to which they can simulate a realistic interview environment, collect performance data from the user, and provide actionable feedback for continued improvement. One major shortcoming of many such tools is that their user experience provides minimal immersion. Such tools often deliver simulations merely through a computer monitor, which continually reminds users that what they are being shown is a simulation and and in turn hampers their ability to benefit from the training experience. They do not support the monitoring of a user's affective state. While they can analyse user inputs, such as response timing and volume, they do not know a user's physical state, which is critical to identifying stressors and providing feedback that will aid the user in overcoming the stressors that impact their performance.

In [18], the authors mention how at present, there is no way of choosing appropriate accessibility options for different users and media except a case-by-case analysis, which is not a scalable approach. Furthermore, they discuss a gap between mainstream system designers and accessibility practitioners in terms of universal or inclusive design. Mainstream designers often assume inclusivity as another 'TopUp' feature and underestimate its need. On the other hand, accessibility practitioners often work for specific types of disability and applications.

In the field of web accessibility, [12] claims that most of the research in this field has been limited to investigating accessibility issues for people with visual, physical, and hearing disabilities. Far less attention has been given to the study of the accessibility of websites to people with cognitive disabilities and specific learning difficulties, such as dyslexia. Very little empirical evidence for the kinds of problems dyslexic users face when using websites has been reported. On the other hand, in [33], the authors who built a web application for dyslexics, say there are no similar applications that offer an alternative to dyslexic users when reading text on the Web. Moreover, it was the first time that eye tracking was applied to dyslexic users to measure textual accessibility.

Although many software solutions and approaches have been carried out to manage neurodivergent issues, there is only little empirical evaluation of the results. Moreover, neurodiversity as a whole is still only being investigated very little, and on a very high level, e.g. applications made for ASD target users without considering the spectrum and broad range characteristics.

Q2 - What approaches have been set to address those issues in software engineering?

In total we found 10 papers ([27], [31], [28], [2], [15], [16], [11], [18], [36], [33]) that answered this question. We will present a summary of the data extracted from each paper related to the question Q2.

In [27], the authors use Adaptive User Interfaces (AUIs) to adapt the way the user interacts with the software system to his characteristics and context of use. First, they define what user characteristics to consider, form a User Model, and build the user interface adaptations based on said characteristics, the Interaction Model.

In [31], the authors perform an anonymous online survey intended as a first step to elucidate information about software and technology use from the user's perspective. Additionally, data was analysed to aid the creation of future technology-based products for people with ASD that are not just effective, but also meet important user goals, and align with their interests and strengths. The goals gathered fell into three domains: social/ communication, academic/school help, and scheduling/organization.

In [28], the author's motivation is to generate guidance for inexperienced designers/ developers for dealing with requirements elicitation in the ASD context. They present two artifacts to support the elicitation of requirements in software projects for autistic users. These artifacts consist of three interview scripts and three canvas, catered towards Caregivers, Specialists and Clients. Each question of the interview script is mapped to the respective sections of the specific canvas.

In [2], the authors develop a mixed-reality training platform, called InterViewR, which combines VR and wearable smart technology in an integrated platform to deliver an immersive training experience with intelligent affective biofeedback. InterViewR is designed to help individuals with ASD walk through the steps of a job interview and monitor feedback to address stressors that are impacting their performance.

In [15], the authors aim to investigate the consequences of writing automaticity and the effect it may have on the understanding of the content of written composition in compensated dyslexia, in a higher-education setting akin to a seminar or lecture. Results demonstrated that the presence of a piece of assistive software improved comprehension and understanding of the content of the transcribed text by the participants with dyslexia only, shown by improved performance in a test of recall, predominantly driven by improvements in the extrapolation from, and the comprehension of the material rather than just recounting basic factual information.

In [16], the authors propose the requirements and design of a mobile application called "Flourish", which is aimed at individuals with ADHD to help them better manage their symptoms and understand how they behave. The goal is to provide a platform containing all the resources that can help ADHD patients effectively. The application includes time management and organization, mindfulness and relaxation, a platform for communicating with other ADHD patients and specialists, habit tracking, and behavioural patterns.

In [11], the authors focus on inclusive design aspects of an animation tool that could show changes to memory that individual instructions make over time. The software helped enhance learning for all students, but dyslexic students to a greater degree. It showed that disabled people can identify subtle hidden aspects of human activity, that the target user population is unable to articulate.

In [18], the authors present the efforts of the Virtual User Modeling and Simulation Standardisation (VUMS) cluster of projects towards the development of an interoperable user model, able to describe both able-bodied and people with various kinds of disabilities. The main goal of the VUMS cluster is the development of a unified user model that could be used by all the participant projects and that could be the basis of a new user model standard. They presented a concept of using user models in both design time and run-time to personalise a wide variety of applications concerning users with a wide range of abilities.

In [36], the author's main quandary concerns the extraction of the requisite information from autistic users to enable the development of a best-suited app for them. In line with the predicaments faced by the requirements engineer in gathering requirements for applications for autistics, they proposed a solution called autistic user requirements engineering.

Meanwhile, in [33] the authors present the first prototype of a web service that makes Web texts more accessible to people with dyslexia. The guidelines for developing this service are based on quantitative and qualitative data collected from a set of experiments carried out with a group of dyslexic users, which in turn they added the following two main contributions: (i) A set of guidelines for displaying dyslexic-friendly text on the Web based on the analysis of an extensive user study which combines qualitative and quantitative data, and (ii) a user-customizable browsing web service that, by default, presents the text according to the dyslexic-friendly guidelines defined.

In conclusion, the authors in the referenced studies focus on creating technology solutions for individuals with disabilities such as ASD, dyslexia, and ADHD. The solutions include the use of AUIs, anonymous online surveys, interview scripts and canvases, mixed-reality training platforms, mobile applications, animation tools, interoperable user models, and a web service that makes web texts more accessible. These solutions aim to improve the user experience by considering the user's characteristics and context of use, helping them meet their goals and overcome challenges. The authors aim to provide effective and inclusive technology that is tailored to the needs of individuals with disabilities

Q3 - Which guidelines have been concluded to solve those issues?

In total we found 7 papers that answered this question ([27], [31], [2], [16], [11], [36], [12]). We will present a summary of the data extracted from each paper related to the question Q3.

In [27], the authors underline the importance of considering exactly where in the spectrum the target user is to properly develop an application targeted for individuals with ASD. The way the task is decomposed in the application is one of the main factors that affect usability the most since it produces a lower cognitive load on the user.

In [31], the authors conclude the following design considerations for applications with ASD as the target user: include suggestions to consider sensory integration issues, make products portable, and make input devices easier to use including multiple suggestions regarding voice activation. Additionally, 22 respondents (19%)requested software designed with fun in mind; the respondents felt developers should consider creating learning experiences as games. Hardware design suggestions included making products more portable and input devices easier to use including multiple suggestions regarding voice activation. Design considerations for software included suggestions considering sensory integration issues by allowing users to set colour and sounds.

In [2], the authors design a VR Interview Simulation Software for ASD, and salient that you should design a system that will empower users to become aware of their behaviour and interaction, identify the areas that need improvement, and adapt them, if necessary. A VR software should provide an immersive virtual environment, support assessment of a user's physical behaviour and physiological state, and present feedback in a manner that is easy for a user to understand and that enhances engagement in training.

Prior research has shown that the level of immersion has a direct impact on a user's learning in virtual simulations, where higher levels of immersion enable users to translate their experience effectively to the real world. The advantage of using VR extends beyond immersion. Having control over what stimuli the user is exposed to allows the simulated interview to be tailored to each user's individual needs. For that reason, their software was designed to allow users to easily customize their training experience through a visual authoring tool. Prior to starting a simulated interview, users can specify the setting of the virtual interview, the interview length, and other general specifications. Users can also configure the amount and type of distractions to raise or lower the difficulty of the simulation.

[16], who designs a system that helps ADHD users organize tasks, has first the application prioritize their chores based on two factors: deadlines and difficulty. After that, the user will be given a schedule with their duties prioritized, allowing them to conveniently begin and complete tasks. A reward will be given once each activity is done to serve as motivation. There will also be a reminder that will send an alert when the task approaches its deadline.

In [11], the authors who design software that could ease the learning for dyslexic students, implement several suggestions to provide access to dyslexic students (such as increased font size, and the colour scheme avoiding black on white). Probably the most significant modification was the inclusion of the tick, which came about as a direct result of interaction between a dyslexic student and the software developer/researcher. This tick is placed to the left of each line as it is executed.

In [36], the authors suggested the importance of a Pre-Study when designing software during which the attributes of the participants are determined, as well as the purview of the research. The said participants should possess the ability to respond spontaneously and promptly and there should be participants for required traits, such as the "lead user" characteristic. The Pre-Study consists on the following phases: interviewing, evaluation, and presentation.

In [12], the authors evaluate 16 websites with a panel of Dyslexic participants. The categories with the most instances of problems encountered by dyslexic users were "information not in page where users expected it to be" and "navigation elements do not help the users find what they are seeking", which account for 28.4% of the instances of problems. These two categories are related to navigation and information architecture issues. The first occurred when users followed a path that seemed logical to them on the website, but the pages did not contain what they expected them to present. The second most frequent category is related to problems when the elements in the navigation did not help users decide where to go to find the information they were seeking.

The third most frequent category was "difficult to scan the page for specific item", which accounted for 10.4%of the problems. This category is related to problems when the user encounters difficulties scanning for specific items on a web page, often due to a lack of structural or visual aids that would make the content they needed stand out from the rest of the web page. The fourth most frequent category was "default presentation of the text is not adequate", with 6.2% of the problems. Common issues included the use of italics, inadequate spacing between lines and paragraphs, small font size, inappropriate font style, and inappropriate colour background. The occurrence of complaints about colour backgrounds is noteworthy.

Many participants encountered problems with black writing on a white background. For these users, reading text on a white background for a long time causes the text to start forming "visual patterns", or "dancing around". Although most web browsers have features to change the colour background of a website, none of the participants of this study knew about this feature, or if they knew, they found it very difficult to use. In most cases when this problem was reported, participants expected that the websites would provide them with a colour selector feature instead. As such, there is a need for more attention to the design of information architecture in websites, and it is important that designers investigate how users find it most logical for the information on websites to be organized.

In conclusion, several articles discuss the importance of considering the target user and their specific needs and preferences when designing software applications. The task decomposition in the application is a key factor that affects usability and should be optimized to reduce cognitive load on the user. Design considerations such as sensory integration, portability, ease of use for input devices, and fun-oriented learning experiences are important. The software should also allow for customization and personalization of the training experience. Pre-study is crucial when designing software, where the attributes of the participants are determined and research is purviewed. Visual aids and the laddering method are recommended for collecting data, and the evaluation phase involves creating visual cards, value maps, and pictorial scenarios to accommodate various features that appeal to the user.

Q4 - Which areas have those guidelines covered?

In total we found 4 papers that answered this question ([31], [28], [16], [33]). We will present a summary of the data extracted from each paper related to the question Q4.

In [31], the authors divide their proposed guidelines for ASD accessible applications into three categories, goals (62%), access concerns (5 %) and design suggestions (33%). Goals were further subdivided into three domains, (a) social/communication; (b) academic/school help; and (c) scheduling/organization.

On the other hand, in [28] the authors organize their guidelines in an autistic's caregiver canvas (ACC). This canvas has seven sections. Section 1 contains general data that directly characterizes the autistic person, and section 2 includes information about her/his social interaction with other people and family. Section 3 presents activities known to parents that calm down her/him. Section 4 presents the opposite case, activities that make her/him more restless than usual. Section 5 lists the repetitive behaviours or manias in his daily routine. Sections 6 and 7 are for information about the autistic person's use of technology and aspects related to the future software ASC also with seven sections. Sections 1,2, 3, and 4 follow the same purpose as sections 1, 3, 4, and 5 of the ACC, respectively.

Finally, section 8 is for adding any extra information that might be needed. Abstractly, we divide the canvas into two areas. The rest consists of sections that refer to the characteristics of the autistic person, such as activities that disquiet, activities that calm, and social, and family aspects, among others. The second consists of sections relevant to the software, such as the purpose and need for the software and restrictive and permitted activities.

In [16], the authors organise their application for ADHD into the following sections: a management and organization section that will help in organizing and prioritizing tasks to make an efficient and effective timetable. The mindfulness and relaxation section will help them with their emotional instability. Finally, the last section tracks habits and any behavioural patterns that can aid in the diagnosis or treatment process.

In [33], the authors consider that the main variables to be analysed regarding the executed tests on dyslexics users are: Problems encountered by users and their severity; Task completion; Difficulty in completing each task; Time to complete tasks; User satisfaction with the website. The severity of each problem should be rated according to the following scale: 1 (Cosmetic – an irritation that is unlikely to cause a serious interruption in completing the task), 2 (Minor – a problem that is likely to interrupt the users for a short period or from which they can recover easily), 3 (Major – a problem that is likely to interrupt the users for a long period or from which they will recover but with some difficulty), 4 (Catastrophe – a problem which will stop the user from completing their task).

In conclusion, the authors of several studies have proposed guidelines for the design of applications aimed at supporting individuals with Neurodivergent conditions. These guidelines cover a range of areas such as goals, access concerns, design suggestions, information about the person, and the functionality of the application. The focus of these guidelines is to provide an effective and efficient tool for individuals and their caregivers, with the ultimate goal of improving their quality of life. The results of the tests conducted demonstrate the importance of considering the users' needs and experiences when designing applications for individuals with Neurodivergent conditions.

Q5 - What concepts have been defined?

In total we found 7 papers that answered this question ([36] , [27], [31], [28], [12], [15], [16], [27], [28], [18]). In this section, we will introduce the main concepts of extracted from the papers: ASD, Dyslexia, ADHD and Requirements Engineering.

Autism Spectrum Disorder [36] classifies ASD as a cognitive disorder of social interaction, impaired communication, and repetitive and restricted interests, also known as pervasive development disorder. It is a set of disorders including Rett syndrome, autistic disorder, childhood disintegrative disorder, and asperger syndrome. [27] explains that the "spectrum" in the disorder's name comes from the unique combination of afflictions in individuals, requiring tailored therapy. [31] defines the triad of impairments in individuals with ASD as communication, socialization, and repetitive, unimaginative, and stereotyped patterns of behaviour. [28] explains the three classes of ASD: high, medium, and low functioning, with low functioning ASD being the most severe with serious communication problems and low cognitive function.

In [36], the authors list the ASD symptoms that appear in the early child mental developmental years between 2 to 3 years of age. They divide the symptoms into two categories, the first being "Communication Problems". This consists of the following symptoms:

- Not talking or less talking;
- Loss of known vocabulary;
- Essential needs and wants not expressed properly;
- Not answering the question properly;
- Poor vocabulary development and repeating what is said;
- Poor eye contact with people or objects;
- Poor participating skill;
- Overly focused on objects or subjects;
- No or less friends;
- Weeping, giggling, becoming angry or laughing for unknown reasons or at the wrong times;
- Disliking being hugged or touched;

The second category is "Reacting to the world around them", which includes the following symptoms:

- Self-stimulated problems;
- Paying no attention to objects or people;
- Not encouraging routine changes;
- Using objects in an unusual way;
- Not fearing real dangers and;
- Sensitive to light, touch or sound;

The authors in [27] state that the symptoms of ASD are caused by impairments in Executive Functions such as working memory, cognitive flexibility, planning, generativity, self-monitoring, and inhibition. Executive Function is a term used to describe cognitive processes necessary for the completion of goal-oriented tasks, typically carried out in the frontal lobes. The authors in reference [36] state that the exact cause of ASD is unknown, but it may be caused by genetic problems or syndromes, severe infections that affect the brain, or exposure to toxins during pregnancy. Research shows that ASD is more common among boys, with a ratio of 1 in 100 to 1 in 320 in girls.

Dyslexia According to [12], dyslexia is defined as a specific learning disability which is neurological in origin and characterized by difficulties with accurate and/or fluent word recognition and poor spelling and decoding abilities. These difficulties often result from a deficit in the phonological component of language, leading to secondary consequences such as problems in reading comprehension. Research broadly agrees on the distinction of three types of dyslexia: phonological, surface, and deep dyslexia. Phonological dyslexia is a disorder of reading characterized by impairment in pseudo-word reading ability, while surface dyslexia is characterized by poor reading of low-frequency irregular words with accurate reading of pseudo-words.

In [15], the authors mention that people with dyslexia have a working memory deficit which can impact their ability to understand what they are writing. Writing is defined as a complex process involving many different functions, integrated by the working memory system, which is defined as a finite temporal storage of information.

Attention- Deficit/Hyperactivity Disorder In [16], the authors define ADHD as a neurodevelopment disorder that is typically identified during childhood and lasts into adulthood. Lack of focus, inability to sit still for long periods, forgetfulness, impulsivity, time management difficulties and disorganization, and emotional dysregulation are some of the early indications of this illness.

On the other hand, [16] focuses on ADHD symptoms, particularly emotional dysregulation as they experience several symptoms such as mood fluctuations, irritability, and temper tantrums. Due to that kind of distress, they often require external assistance to be able to stay motivated and not succumb to their emotions.

Requirements Engineering In [27], the authors define a conceptual model related to Software. They conclude with the following definitions:

- software is a set of functionalities operated by the user, which also includes a user interface
- User Interface Pattern can be defined as a set of GUI components and/or interaction styles for addressing a particular interaction problem which in turn also needs certain user characteristics to operate said pattern. With this said, for each task, there are user interface patterns that can achieve the task
- A user has a set of characteristics needed for software interaction
- The user interacts with the system with Graphical User Interface
- A task involves a set of actions executed by the user. An action can be of one of the following types: input, indication or interpretation. An input action involves operating an input device, such as a mouse, keyboard or microphone; with the appropriate user attribute, such as hands and voice. An indication action also involves

using the same user attributes as input but also involves perception, attention, and information processing. A perception-action involves employing the senses such as eyesight, hearing or touch. An information processing action involves employing cognitive functions such as working memory and cognitive processor

In [28], the authors define requirements engineering as a crucial stage for the success of any software, as it allows a better understanding of the needs and desires of the customers or future users. In software development for autistic users, inexperienced software engineers face difficulties in the requirements engineering stage, as there are few specific techniques and artifacts to gather requirements in such a context. During the requirements elicitation phase, requirements engineers obtain the functionalities of the new software from customers and users. They also identify information about business rules, constraints, and usability characteristics. interview technique is one of the most widely used for requirements gathering Other requirements elicitation techniques are questionnaires, document analysis, prototyping, and ethnography. They also define interview scripts as a series of questions to be asked of caregivers, specialists, and clients to collect information. Such questions address both aspects related to the context of neurodivergent people and the application itself.

In [18], the authors claim that the use of user models can be very valuable when trying to develop accessible and ergonomic products and services taking into account users' specific needs and preferences. Simulation of user-product interaction using user models may reveal accessibility issues at the early stages of design and development, and this results in a significant reduction in costs and development time. User modelling provides a way of choosing an appropriate feature or service based on the user and the context of use. It is implemented as a simulator to model the effect of impairment during design, which will help designers to visualise problems with people with age-related or physical impairment. The user model is also used as a means of adapting interfaces in run-time to further customise systems for different users VUMS.

Main RQ - Which issues do neurodivergent people face in Software Engineering?

Studies on the integration of software solutions for autistic individuals have shown a need for more research in the field. Characteristics such as the user's age, verbal or non-verbal skills, and functioning level must be considered during the development process. However, it can be difficult to find methods for surveying software requirements for this audience. There is a gap between mainstream system designers and accessibility practitioners in terms of universal or inclusive design, with most research focusing on accessibility for those with visual, physical, and hearing disabilities.

Several studies have been conducted to create technology-based products for individuals with disabilities, including AUIs, online surveys, mixed-reality training platforms, mobile apps, and dyslexic-friendly web services. The design of software applications for individuals with ASD must take into account factors such as task decomposition and sensory integration to lower the cognitive load on the user. In some studies, users have requested software designed for learning experiences, and design considerations for hardware include making products more portable and easier to use.

The authors of these studies have proposed guidelines for the design of applications for people with ASD, covering aspects such as goals, access concerns, and design suggestions related to social/communication, academic/school help, and scheduling/organization. These guidelines also cover information about the person with ASD, including their social interactions, behaviours, and use of technology. Tests are conducted to evaluate problems encountered by users, task completion, difficulty, time to complete tasks, and user satisfaction.

3.2 Related work

In [1], the authors conduct a SLR to find out how to develop software solutions that are adapted to users with ASD and establish a set of recommendations to guide software developers and designers. The objective was to identify specific recommendations that would enable software developers to create adequate solutions for users with ASD. They claim the vast majority of ASD software solutions described in the literature are prototype versions that have simply been validated as proof of concept. There has only been limited assessment of how well they work in real-life situations, making it difficult to gauge the quality of the solutions reported in the literature. The design of these solutions often fails to take into account their end-users characteristics, limitations, needs, and expectations. nonfunctional requirements such as ease of configuration, customisation, and portability are not always considered in accessibility solutions.

After conducting the SLR, they put together the information into a set of guidelines that outline the usability and functional requirements for a digital tool aimed at individuals with ASD and their caregivers. The tool should be useful, efficient, and functional. It should also have a long lifespan and high availability, have the same appearance as popular devices, have a large screen, low battery consumption, good camera, and microphone, and be easy to use without hand-eye coordination. It should be protected by a password, allow caregivers to define objectives and exchange experiences, and have the ability to import and export information. The tool should also be adaptable and allow for personalization in various ways, such as the interface, performance evaluation, interventions, and media. The guidance section emphasizes the importance of clear and simple tutorials, logical navigation, clear images, and minimal distractions. The workload section recommends a clear and simple interface, display modes, and avoiding exposure to too much information. The compatibility section highlights the importance of considering demographic characteristics, language, and providing appropriate instructions. The explicit control section emphasizes the importance of ensuring that users with ASD have control over the application and the ability to personalize it.

In [25], the authors perform a systematic mapping study in order to investigate the adopted strategies for conducting software technology evaluations that target ASD users and how to obtain data related to their experience with software technologies. They claim that most of the related works done previously, simply focus on educational technologies, and do not focus on a specific kind of technology. As such they aim to investigate how methods and procedures are being adopted to evaluate software technologies with autistic users. The authors found that most studies conduct user testing, while exceptionally one conducted an inspection evaluation. Different data collection methods were used such as observation, questionnaires answered by clinicians or parents, and application logs. Questionnaires were used to characterize ASD aspects, while application logs were used to evaluate user performance in games or educational software. The test environments were mainly classrooms and clinics, with teachers and clinicians involved in mediating user interaction and providing data for analysis. Parents were involved in longitudinal user tests in classrooms to provide information about the improvement of social and life skills or child preferences.

In [5], the authors present a study that involved the design and implementation of a prototype extension for a Web browser that offers customization features of Web pages, based on requirements from problems encountered by users with dyslexia in related studies in the literature. The main goal of the work reported in this paper was to investigate the needs of dyslexic users when using the Web reported in the literature, and based on the requirements elicited, to implement a prototype of a browser extension for Google Chrome to offer features to help the navigation of dyslexic users, called WebHelpDyslexia.

This extension enables users to change text size ranging between 12 and 26 points. The typeface of text can also be altered by the extension, including the options: Open Dyslexic, Comic Sans, Arial, Verdana, Georgia, Tahoma e Trebuchet MS. Priority was given to fonts sans serif. Fonts with too much decoration can make reading more complex. The extension also enables removing italics, bold and underlining. The use of italics can cause visual effects in which the words seem to be blending, and this effect can be aggravated when small fonts are used. changes in foreground and background colours. The extension allows changes in those colours for all the text on web pages. Dyslexic users may find great difficulty. Some guidelines recommend using darker text colours on a pale lighter background, such as a dark blue on a crème background. The most frequently used colour combination by dyslexic users was black text on a yellow background. Changes to paragraph and text spacing and alignment were another set of important features implemented on WebHelpDyslexia. The first of such features enabled removing text justification and making text left aligned. WebHelpDyslexia also enables users to change character spacing within paragraphs, with options of 0%, 7% and 14%. The tool also enables users to choose the length of lines in paragraphs, to avoid having very long lines that may make it harder for them to read. Providing features to help dyslexic users highlight text helps them significantly to have a better comprehension of text.

WebHelpDyslexia enables users to choose the colour they want to use to highlight parts of the text they find important, There is also a feature that fades the page being read by users and leaves only one part visible for reading: "reading ruler". Finally, they implemented a preliminary prototype of a synonyms search to help understand difficult words used in the text.

In [10], the authors conduct research that enhances InterViewR by addressing the initial feedback. An evaluation of the resulting system was then conducted to identify additional areas that can improve the quality of similar systems. In this paper, the aim was to discuss the areas that can be improved to provide an optimal interview training experience using a mixed reality system such as InterViewR. InterViewR is a job interview simulator combining VR and wearable smart technology to create immersive training experiences. The research involved reviewing literature published post-2019 to compare InterViewR's design to the most current VR technology and training techniques. The results showed that VR headsets can immerse users in simulations and improve their focus, leading to more effective skill transfer. Both AR and VR are more engaging in teaching skills than traditional methods such as lectures and flashcards. Studies show that VR classrooms can help students who struggle with focus and eye contact. One study employed gamification to treat auditory hypersensitivity. The VR headset provides immediate feedback on performance and physiological distress. Improvements to the user interface and instructions could enhance the user experience of the VR headset.

In [14], the authors perform a SLR to uncover, analyse, and presenting design characteristics of VR systems that have been designed as training tools for individuals with ASD. Specifically, this review sought to: assess points of convergence and divergence in how researchers define VR, extrapolate individual components of VR systems, and systematically extract how design factors are instantiated in these VR projects.

In [9], the authors provide a two-fold contribution to the HCI field: A guideline for conducting studies with users with ASD as well as suggestions on how to report these studies. we present a critical review of user experience studies conducted with autistic users from any age group within the last 7 years. The paper therefore has two aims. First, they seek to explore how researchers in this area characterize and define VR. Second, they seek to uncover, analyse, and present the design characteristics of VR systems that have been designed as intervention or training tools for individuals with ASD.

The results were gathered and presented in the form of guidelines that provide a comprehensive overview for conducting user experience studies with individuals who have ASD. The guidelines emphasize the importance of knowing the participants, familiarizing them with the study environment, having a plan B in case of data collection failures, and providing detailed reporting of the study. The guidelines also recommend that researchers understand the individual capacities and strengths of participants, and learn about their environment, prior experiences, and interests, to conduct a successful study. Researchers should also train actors involved in the study and familiarize participants with the study environment, materials, and tools used. To ensure the success of the study, researchers should also have backup plans in case of data collection failures, and be flexible in their approach. The guidelines emphasize the importance of detailed reporting, including participant characteristics, facilitation details, and any problems encountered during the study.

In [41], the authors classify serious games about ADHD according to different platforms developed by video games and then conduct a systematic review of video games that can help children with ADHD diagnose and treat. Finally, they discussed and made suggestions based on the current development of Serious Games about ADHD. The results show that several computer games have been developed for diagnosing and evaluating ADHD using different approaches and technologies. These games use diagnostic criteria such as DSM-IV and DSM-V, and evaluate the player's performance in terms of mouse clicks, answers chosen, time spent, and executive function deficits. Some of these games use brain-computer interaction technology to obtain EEG data, and machine learning to classify this data for an accurate diagnosis.

The games also use VR to create an immersive environment and train the player's attention, memory, and concentration. Feedback questionnaires are used to help players adjust their training. Finally, the authors also conclude that VR provides an immersive environment that can provide a real sensory experience during the diagnosis process. On the other hand, machine learning can classify the data obtained during the game and increase the accuracy of diagnosis. By using some EEG acquisition equipment to obtain the EEG data of patients with ADHD in the game process, and then provide real-time feedback to patients through the screen or sound in the game, it can help patients with ADHD to train their ability of concentration. To accurately capture the different states of brain activity, some studies proposed EEG signal processing method based on the fractal dimension model and successfully applied it to serious games.

Overall, these studies highlight the importance of considering the specific needs and characteristics of individuals with special needs in developing and evaluating technology for them.

3.3 Summary

In this chapter, we conducted a SLR what issues neurodivergent people face in software engineering and how those issues have been addressed. We examined various studies and methodologies aimed at designing software and technology to support individuals with neurodevelopmental disorders and listed the main concepts and guidelines. In the next chapter, we will develop the conceptual model based on the results of the literature review.

4

A Conceptual Model on Neurodivergent Issues in Software Engineering

Through the state-of-the-art research, we gathered the required information to effectively understand the concepts related to neurodivergent accessibility in software engineering. This chapter explains the process of defining the concepts and relationships and presents a conceptual model on neurodivergent concepts in software engineering.

4.1 Methodology

With the conceptual model, we aimed to outline the neurodivergent concepts and relationships that must be taken into consideration during the software development process, to ensure that the software meets the needs and requirements of neurodivergent individuals.

The methodology used to build the conceptual model was inspired by [30], which describes ontology the process to build an ontology. The author describes an ontology as a formal, explicit description of concepts within a specific domain. It typically consists of classes (concepts), properties (slots or roles), and restrictions on properties (facets). We adapted the steps listed to a conceptual model and finally followed the process described bellow:

1. **Determine Domain and Scope**:

    - Start by defining the domain and scope. This involves answering basic questions such as what the conceptual model will cover, its intended use, the types of questions it should answer, and who will use and maintain it. This step helps in limiting the scope of the conceptual model and focusing on relevant concepts within the domain.

2. **Enumerate Important Terms**:

- Create a comprehensive list of terms relevant to the domain. These terms may include nouns (objects) and verbs (relationships) that describe entities and actions within the domain.

3. **Define Classes and Class Hierarchy**:
   - Develop a hierarchy of classes based on the identified terms. There are several approaches to class hierarchy development, including top-down, bottom-up, or a combination of both.
   - Start with general concepts and progressively specialize or generalize them as needed to represent the domain accurately.

4. **Define Properties of Classes (Slots)**:
   - Once classes are defined, describe the internal structure of these concepts by specifying their properties.
   - Identify attributes or characteristics associated with each class and define slots (properties) to represent them.

5. **Define Facets of Slots**:
   - Slots can have different facets describing their characteristics, such as value type, allowed values, and cardinality (number of values).
   - Determine the value types for slots (e.g., string, number, boolean) and specify any restrictions or constraints on allowed values.

We used this methodology to form the concepts of our model and create a conceptual model. The model was created using an iterative process with a mixed approach using the tool StarUML. The concepts were represented as classes and the conceptual model was built as a UML class diagram.

4.1.1 Specification of the domain

Before starting to review the information to define the concepts, it is important to define the domain and scope of the model. That is, it is important to determine what questions the information on the model address.

To define the domain and the scope of the model we decided to answer a few questions to help us understand what requirements our model should follow and what information it would include.

Table 4.1: Domain Questions

What is the domain covered?	The intersection between neurodivergent issues and software requirements.

What will it be used for?	To assist the requirements elicitation process for a neurodivergent accessible software.
What questions will it answer?	The issues neurodivergent people face when using software and what requirements can be implemented to mitigate them.
Who will use it?	Software engineers in the requirements elicitation process.

4.1.2 Important terms

During the state-of-the-art research, we gathered a lot of information on the subject. While we selected which information to extract from the papers selected, we paid close attention to specific terms that related to our study and that could be relevant for us to include in the conceptual model. At the end of the research, we scanned all the information extracted (discussed at the end of Chapter 3) and transformed it into keywords or phrases that could potentially be transformed into concepts for the model.

The keywords were eliminated and modified after several read-throughs, with the criteria for elimination being the ones defined during the domain construction shown in table 4.1.

To create a starting point for the construction of the conceptual model, we started by creating a mindmap using the terms selected as a way of brainstorming relationships (see 4.1)[1]. The first terms included were the ones considered directly relevant to the domain of the conceptual model: "Neurodivergent Condition", "Dyslexia", ASD and ADHD.

To better understand the relationship between the terms, we organized them into two categories: difficulties related to software use and solutions to accommodate those issues. Each issue might be related to more than one solution. The result from this categorisation is shown in table 4.2.

Finally, we were left with a first draft of the schema for the model and a list of terms to be included in the model, iteratively.

4.1.3 Identified Concepts

The next step was to define the first concepts and translate them into classes to include in the class diagram. Based on the mindmap built, we defined the first concepts to be included in the conceptual model as well as the relationships between them. These definitions are included in the following table 4.3.

[1] Built using the diagrams.net tool

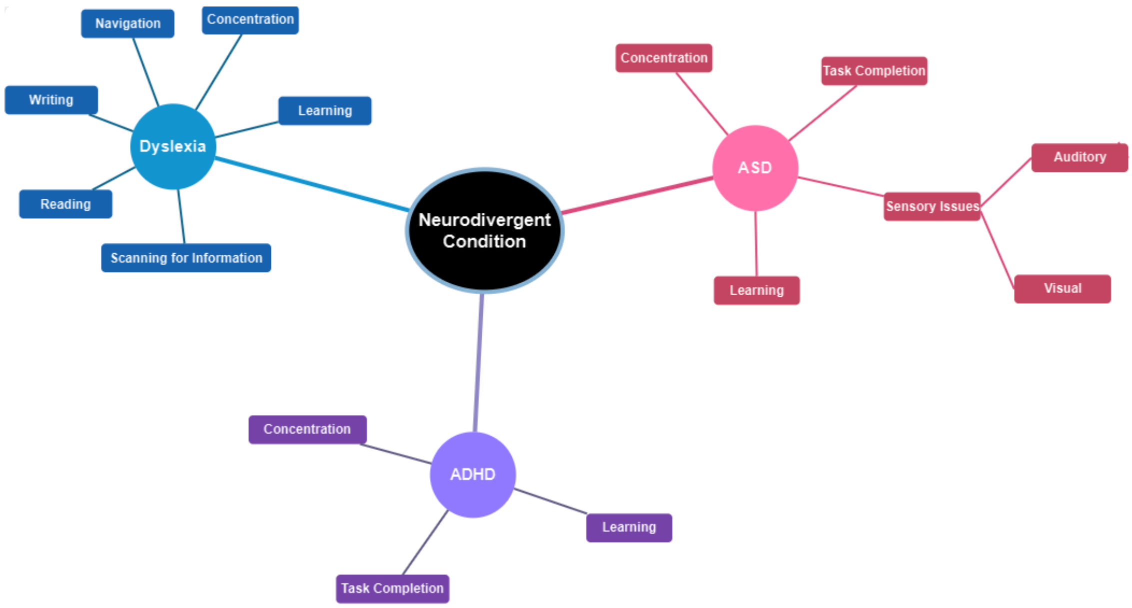


Figure 4.1: Mindmap of Neurodivergent Conditions

Table 4.2: Terms - Issues and Solutions

Issues	**Solutions**
Reading	Sound Control
Navigation	Interface Styling
Scanning for Information	Media Features
Concentration	User Guide
Writing	Feedback Sharing
Learning	Interaction Elements
Sensory Issues	Progress Tracker
Task Completion	Reading Aid
Auditory	VR
Visual	Limited Information
	Reminders
	Rewards
	Schedule
	Visual Aids
	Organisation of Content
	AUIs
	Spellchecker
	Autocomplete

Table 4.3: Central Concepts

Concept	Definition
Neurodivergent Condition	Neurodiversity is the diversity of human brains and minds. Neurodivergent, or ND, refers to individuals whose brain functions differ significantly from societal norms of "normal." This can be due to genetic factors, experiences altering brain function, or a combination of both. Examples include autism and dyslexia [37].
Autism Spectrum Disorder	ASD is a lifelong neurological disorder and is characterized by deficits in communication and social interactions, as well as restrictive and stereotyped behaviours. [14] There are three classes of ASD: high, medium, and low functioning, with low functioning ASD being the most severe with serious communication problems and low cognitive function [28].
ADHD	ADHD is a neurodevelopmental disorder usually detected in childhood and persists into adulthood. Common symptoms include lack of focus, restlessness, forgetfulness, impulsivity, time management issues, disorganization, and emotional dysregulation [16].
Dyslexia	Dyslexia is a specific learning disability which is neurological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties often result from a deficit in the phonological component of language, leading to secondary consequences such as problems in reading comprehension. Research broadly agrees on the distinction of three types of dyslexia: phonological, surface, and deep dyslexia [12].

4.1.4 Identified Relationships

Finally, we were able to form relationships to be included in the class diagram. Each relationship was justified with the source of information that proves its validity; each is explained in the table 4.4.

Table 4.4: Relationships

Relationship	Source
Neurodivergent Condition isExtendedBy ASD	-
Neurodivergent Condition isExtendedBy ADHD	-
Neurodivergent Condition isExtendedBy Dyslexia	-

Table 4.5: Relationships (cont.)

Relationship	**Source**
Dyslexia Has_issue_with Navigation	In the study conducted by [12], the results identified several common problems encountered by users with Dyslexia on websites. Some of the difficulties found were related to navigation: Issues included information not where users expected it and navigation elements not aiding in finding desired information.
Dyslexia Has_issue_with Reading	According to [5], Dyslexia is a specific learning difficulty, characterized by difficulties in activities related to reading and writing.
Dyslexia Has_issue_with Scanning for Information	In the study conducted by [12] to people with Dyslexia, users showed difficulties with highlighting and scanning information for specific items.
Dyslexia Has_issue_with Learning	According to [12], Dyslexia is a specific learning disability which is neurological in origin.
Dyslexia Has_issue_with Concentration	The authors in [13] state that there is evidence of auditory processing deficits and ADHD in dyslexics. Recent research suggests that the auditory deficit in dyslexics could have similarities to the wider visual perceptual mode.
Dyslexia Has_issue_with Writing	The authors in [15] describe Writing as a complex process involving many different functions, integrated by the working memory system. People with dyslexia have a working memory deficit, which makes concentrating on writing quality difficult.
Dyslexia Has_issue_with Task Completion	The authors in [15] state that Dyslexics have a working memory deficit. The authors in [27] define executive function as a term used to describe cognitive processes necessary for the completion of goal-oriented tasks, and working memory is part of the executive functions.
Writing Solved_by Spellchecker	The authors in [32] state that poor spelling is a challenge faced by people with dyslexia and therefore Spellcheckers are a crucial tool for people with that condition.
Writing Solved_by Autocomplete	The findings for the study conducted by [8] indicated that the autocomplete function may reduce the effect of dyslexia on search behaviour for some users.
Learning Solved_by User Guide	In [1] the authors advise software to include a clear and simple tutorial that focuses on user tasks and is supported by a video.

Table 4.5: Relationships (cont.)

Relationship	**Source**
Navigation Solved_by Organization of Content	According to [12], the prevalence of navigation-related problems points to the need of more attention to the design of information architecture in websites. It is important that designers investigate how users find it most logical for the information on websites to be organised.
Navigation Solved_by Interaction Elements	The second category mentioned by [12] is related to problems when the elements in the navigation did not help users decide where to go to find the information they were seeking. The prevalence of navigation-related problems points to the need for more attention to the design of information architecture in websites. It is important that designers investigate how users find it most logical for the information on websites to be organised.
Reading Solved_by Reading Aid	[11] mentions several suggestions that were implemented specifically to provide software access to dyslexic students. Probably the most significant modification was the inclusion of a line tick, which came about as a direct result of interaction between a dyslexic student and the software developer/researcher and highlights the line that is being read.
Reading Solved_by Interface Styling	[11] mentions several suggestions that were implemented specifically to provide software access to dyslexic students (such as increased font size, and the colour scheme avoiding black-on-white)...Common issues included the use of italics, inadequate spacing between lines and paragraphs, small font size, inappropriate font style, and inappropriate colour background.
Scanning for Information Solved_by Visual Aids	In [12] Dyslexic users encountered difficulties scanning for specific items on a web page, often due to lack of structural or visual aids that would make the content they needed stand out from the rest of the web page.
ADHD Has_issue_with Concentration	According to [16], lack of focus, inability to sit still for long periods of time, and forgetfulness, are some of the early indications of ADHD.

Table 4.5: Relationships (cont.)

Relationship	Source
ADHD Has_issue_with Learning	According to [22], ADHD is a disorder of self-regulation and its underlying executive functioning, and define Executive function (EF) as an umbrella term used for a range of cognitive processes, including planning, working memory, attention, and inhibition.
ADHD Has_issue_with Task Completion	According to [16], people with ADHD experience forgetfulness, time management difficulties and disorganization, which detriments their ability to complete tasks.
Task Completion Solved_by Reminders	The authors in [16] develop an app to help ADHD users complete their tasks. One of the requirements was to have a reminder that will send an alert when the task approaches its deadline
Task Completion Solved_by Schedule	The authors in [16] develop an app to help ADHD users prioritize their chores based on two factors: deadlines and difficulty. The user is given a schedule with their duties prioritized, allowing them to conveniently begin and complete tasks.
Task Completion Solved_by Rewards	The authors in [16] develop an app to help ADHD users complete their tasks. A reward is given once each activity is done to serve as motivation.
Task Completion Solved_by User Guide	Have a clear and simple tutorial that focuses on user tasks and is supported by a video [1]
Task Completion Solved_by Progress Tracker	[1] advises to provide an indication of task progress.
Task Completion Solved_by AUIs	In [27] the authors conclude that in order to develop software that is able to accommodate the user's diverse characteristics, there should be applied an AUIs, in order to adapt the way the user interacts to the software system to his characteristics and context of use.
Interface Styling isPartOf AUIs	-
Limited Information isPartOf AUIs	-
Media Features isPartOf AUIs	-
Interaction Elements isPartOf AUIs	-

Table 4.5: Relationships (cont.)

Relationship	**Source**
Concentration Solved_by Visual Aids	The authors in [36] mentioned that due to the user's short concentration spans, it was necessary to accommodate the working memory limitations with the dependence on visual aids.
Concentration Solved_by Adaptive User Interface	In [1] the authors advise the use of an (self-)adaptive interface based on usage history and user's needs and preferences. And avoid the presence of irrelevant information (source of distraction in audio, image, text, etc.).
Concentration Solved_by VR	In [10] the authors, who were designing a VR applications for users with ASD, claimed that a VR headset can immerse a user in a simulation by blocking outside distractions, improving their focus and the effectiveness of learned skill transfer.
ASD Has_issue_with Task Completion	The authors in [27] define executive function as a term used to describe cognitive processes necessary for the completion of goal-oriented tasks, and state that many of the symptoms of ASD originate with impairments in the Executive Functions, such as in working memory, cognitive, and planning.
ASD Has_issue_with Sensory Issues	The authors in [9] define ASD as a neurodevelopmental disorder characterized by various sensory perceptual and cognitive issues.
ASD Has_issue_with Concentration	Many of the symptoms of ASD originate with impairments in the Executive Functions, such as in working memory. The authors in [36] also state that autistics have short concentration spans as a result of working memory limitations.
ASD Has_issue_with Learning	The authors in [27] state that many of the symptoms of ASD originate with impairments in the Executive Functions, such as in working memory.
Sensory Issues isExtendedBy Auditory	-
Sensory Issues isExtendedBy Visual	-

Table 4.5: Relationships (cont.)

Relationship	Source
Auditory Solved_by Media Features	In [1] the authors list requirements necessary to make a software accessible to users with ASD. They state software solutions designed for users with ASD must react to the context and these users' needs and preferences. They must therefore, personalise the media (insertion of images, photos, videos, audio, texts, etc.) and media features (image size, contrast, volume, audio and video speed, text font, etc.).
Auditory Solved_by Sound Control	In [1] the authors advise to avoid the use of disturbing sounds (explosions, sirens, etc.)
Visual Solved_by AUIs	The authors in [1] state that it is necessary to create software solutions that are adapted to users' cognitive, motor and sensory characteristics, and as such it is necessary to allow a vast range of personalisation and configuration options according to the user's sensory particularities.

4.1.5 Multiplicity and Class Attributes

Finally, the last step was to translate some definitions into class attributes and add multiplicity to the relationships. We followed the standard UML syntax as described in [26]. These were translated using the String, Integer or Boolean syntax classifications. Figure 4.2 illustrates the attributes included in some specific concepts. With the definitions listed in table 4.4 we identified the key characterisations that should be included as attributes. For example, given that there are various classes of Dyslexia, we concluded that should be included as an attribute.

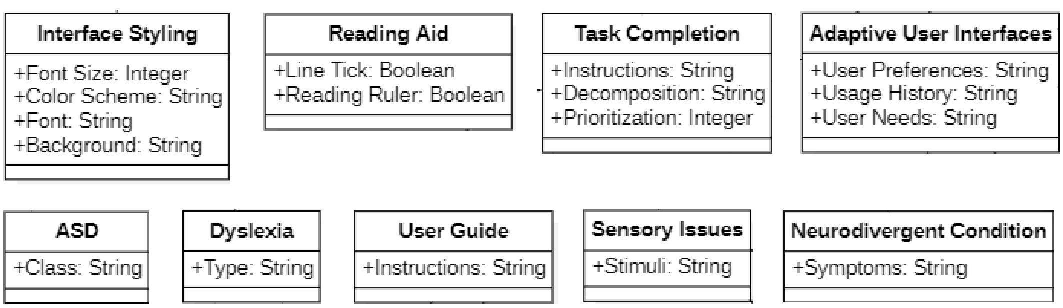


Figure 4.2: Class Attributes

4.1.6 A Conceptual Model on Neurodivergent Issues

In this section, we will present the final version of the conceptual model. Due to its size and to make sure it is legible, we divided the model into three submodels. The first submodel is related to ASD and can be seen in the Figure 4.4, the second submodel is related to Dyslexia and is shown in Figure 4.5, and finally, the last submodel is for ADHD and is shown in the Figure 4.6. They all can be seen in the appendix B. The complete model can be seen in Figure 4.3 and also in appendix A for better resolution.

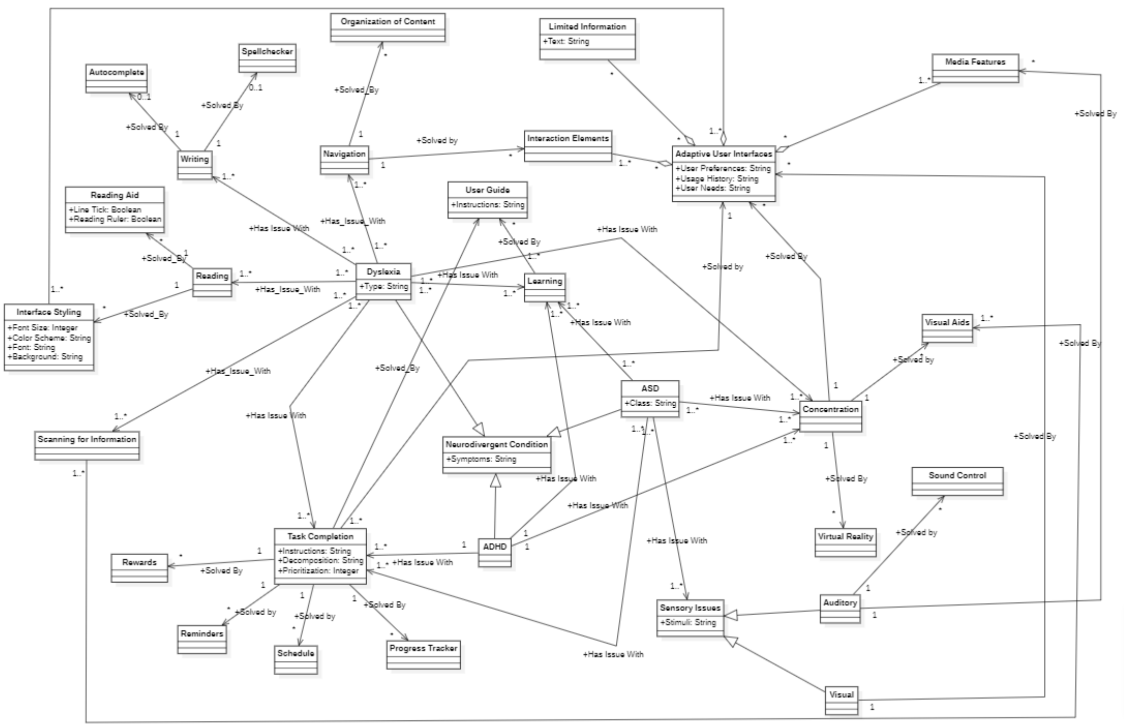


Figure 4.3: Conceptual Model on Neurodivergent Issues in Software Engineering

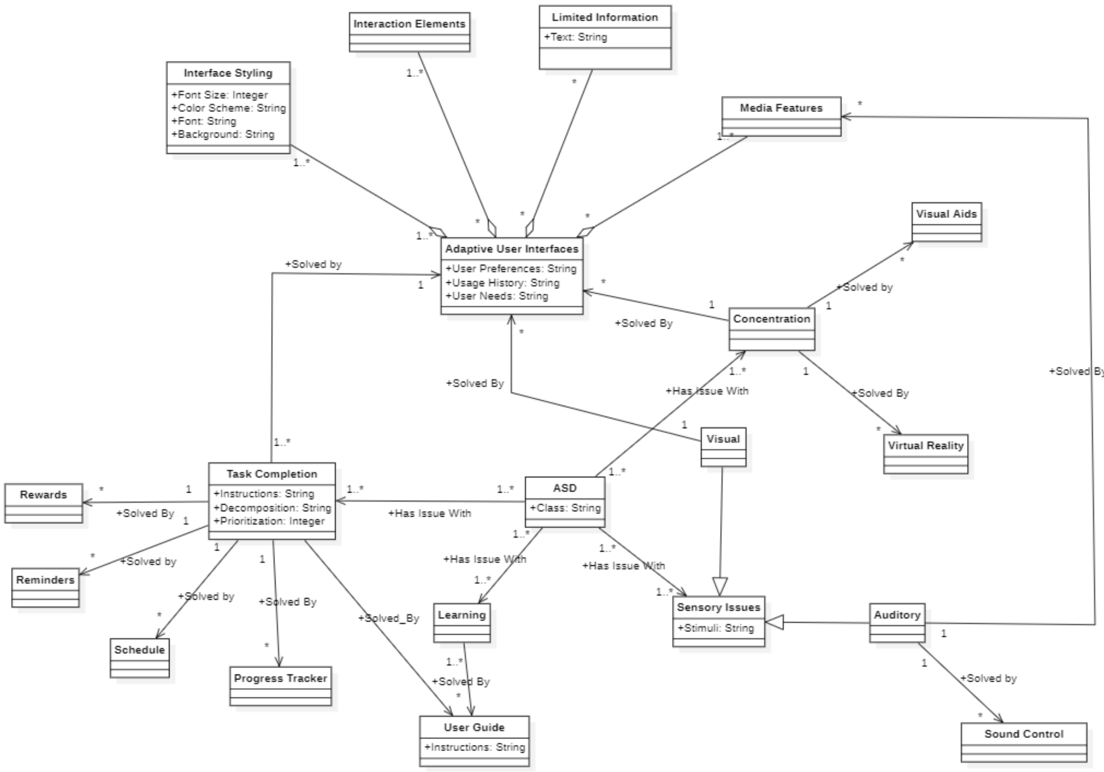


Figure 4.4: Sub Diagram for Autism Spectrum Disorder

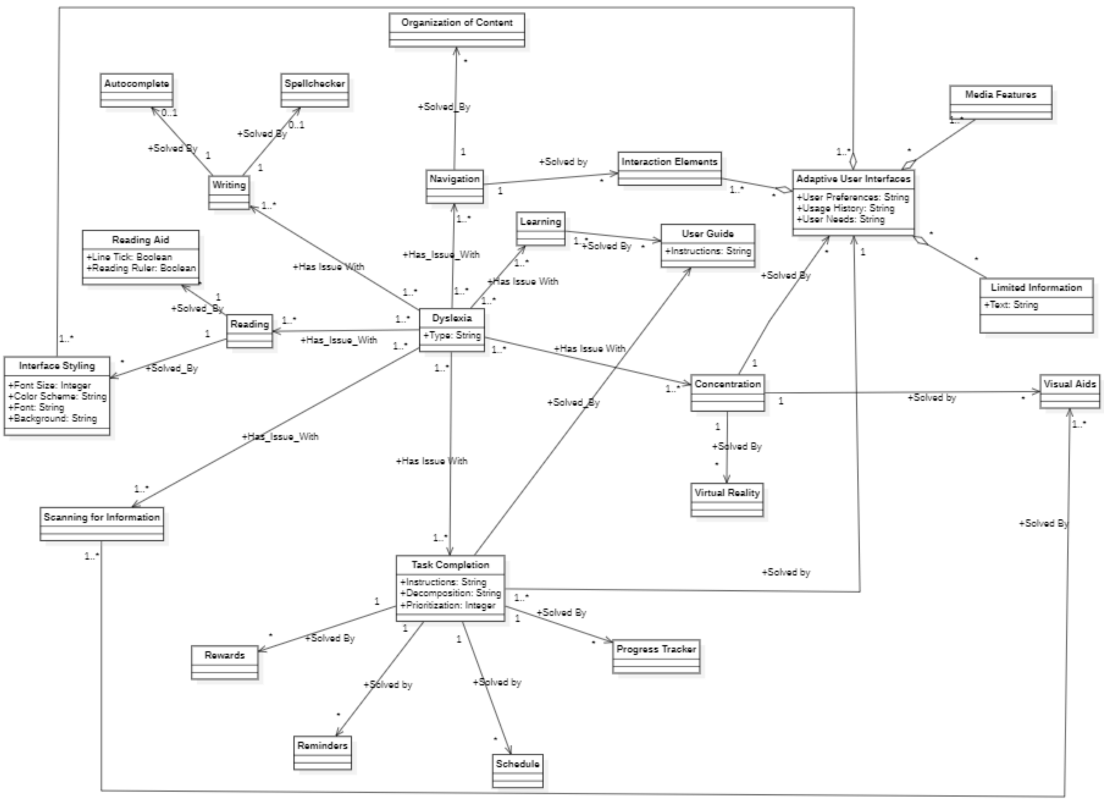


Figure 4.5: Sub Diagram for Dyslexia

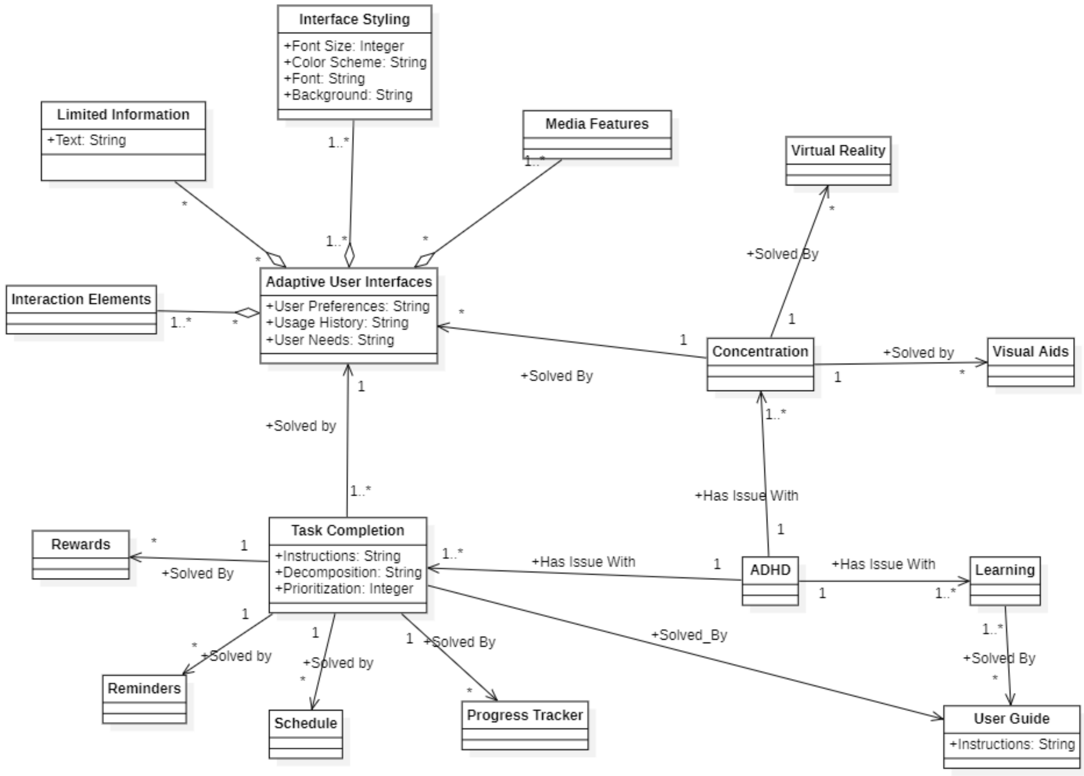


Figure 4.6: Sub Diagram for ADHD

Example of Use

Finally, we applied the model to a use case scenario. In this example, a software engineer is developing an educational application for students and wishes to ensure his requirements accommodate dyslexic students as well. He decides to apply the conceptual model outlined in this chapter to guide his development process.

1. Study the model to understand what challenges Dyslexic users face. He will then look at the guidelines identified as solutions and make a requirements list.

2. Pay close attention to the organization of content on the page and the interaction elements to make sure they are intuitive and clear, to ease navigation.

3. Ensure that every page has visual elements to support text and the interface has a styling that aids reading.

4. In case the software does not support the features already, he will add a spellchecker, a smart auto-complete and a reading aid options as additional features.

By applying the conceptual model on neurodivergent issues in software engineering, the software engineer successfully developed a software tool that is tailored to the needs of dyslexic individuals.

4.2 Conclusion

In conclusion, we consider that the model developed provides a clear understanding of the main issues people with Dyslexia, ASD and ADHD face when using software. It represents the main concepts as well as the relationships between them and identifies all the requirements needed to solve them. To evaluate the model, we performed a survey analysis as explained in Chapter 5.

5

Conceptual Model Evaluation

After developing the conceptual model, the next step is to evaluate the conceptual model through a survey The methodology and analysis of the results are described in the following sections.

5.1 Methodology

Our goal is to build a conceptual model of the neurodivergent struggles while using software to make it accessible. Based on the concepts and relationships we searched and defined in the previous chapter we were able to produce a well-defined model. To improve those concepts and validate the model we decided to survey the use of Google Forms. The survey was sent to end software users to gather feedback on their software experiences and the answers were processed with the use of statistical analysis. The evaluation of the model using the survey consisted of three main phases: developing the survey, result analysis, and conceptual model integration.

5.1.1 Developing the survey

To develop the survey we followed the methodology described in [40] that we considered to be an efficient way of building the questions and systematically improving them to produce the optimal results from the user answers. This methodology consists of 4 well-defined steps that will be documented below.

Step 1: Establishing the survey objectives

To create a survey that applies exclusively to our objectives and can meet them, we began by defining the two main parameters: goals and population. The population includes everyone to whom our conceptual model results could be applied to, that is everyone from all ages that accesses software or websites as end users, and the goals answer the question of "What information do we need to obtain from the survey?". Both are defined in Table 5.1.

Table 5.1: Survey Objectives.

Population	Everyone of all ages that accesses software or websites as end users.
Goals	Confirm that struggles defined by neuro-divergent users during software usage are truthful.
	Confirm that our solutions to the neuro-divergent struggles during software usage are effective.
	Inquiry of additional struggles or solutions we might have missed, thus making the model more complete.

Step 2: Writing and evaluating the questions

The next step was to decide which tool to use to build the form. We decided on Google Forms as we found it to be the most intuitive and although simple, could meet all the needs of our questions. We proceeded to write down the questions based on the goals defined in the previous step. Every concept of our model qualified as "Issue" was transformed into a question of significance with a scale of 1 to 5 to assess its relevance and validate its importance. An example of that is illustrated in the image 5.1.

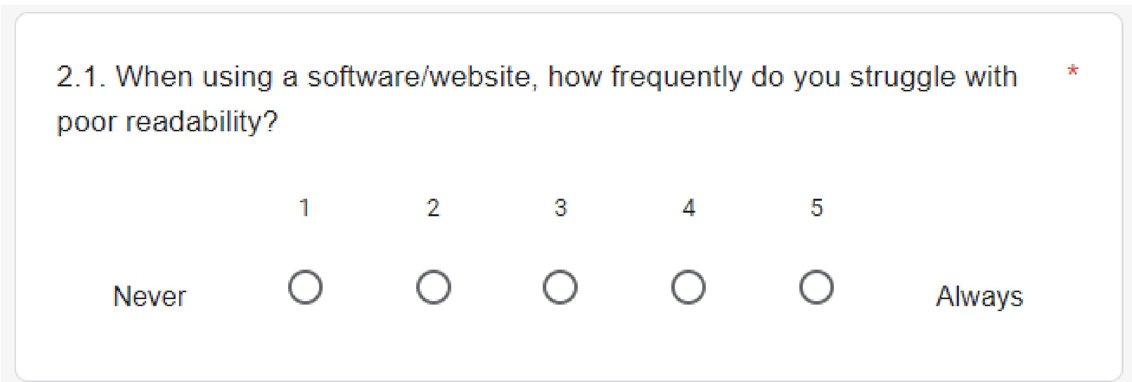
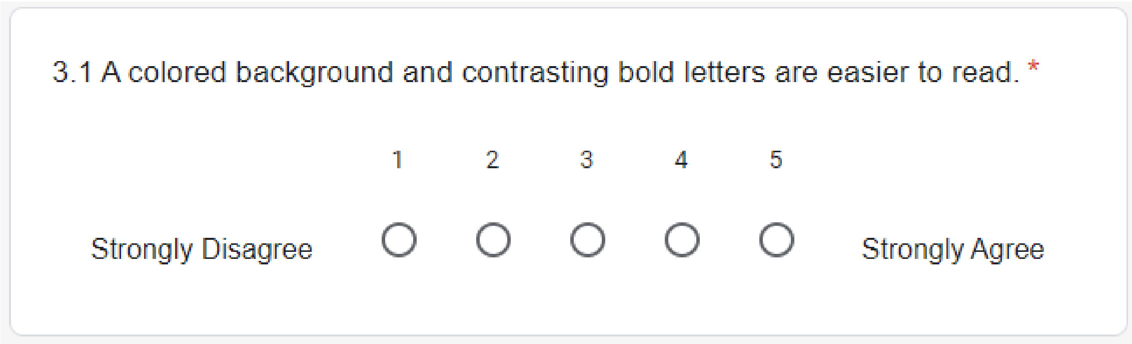


Figure 5.1: Section 2 Example Question

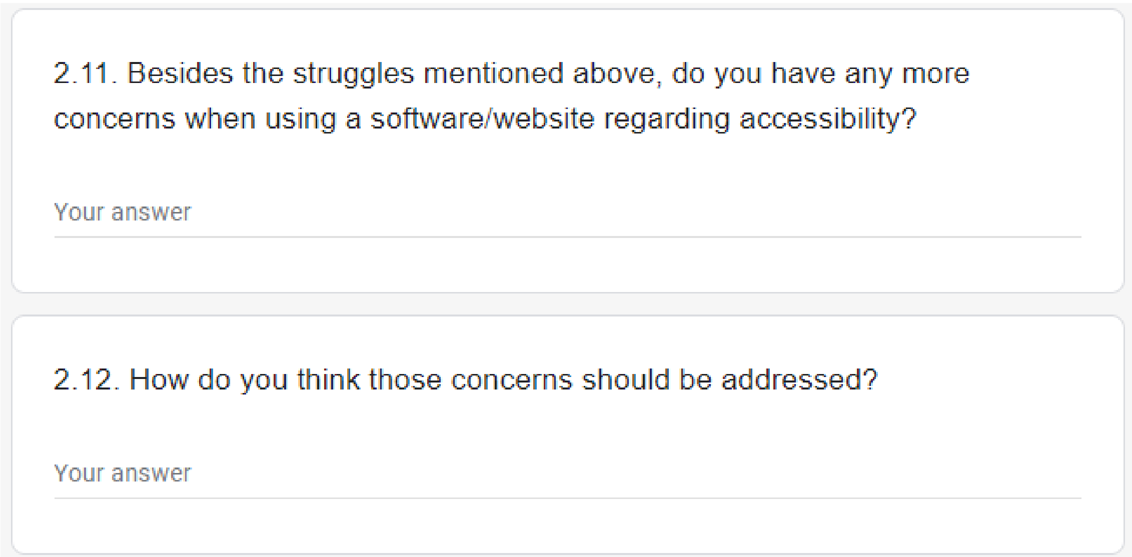
On the other hand, solutions to those issues were given a question that could verify its efficiency and validate the issue-solution relationship, as exemplified in the image 5.2.


3.1 A colored background and contrasting bold letters are easier to read. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Figure 5.2: Section 3 Example Question

Finally, we made sure to include two open-ended questions that could provide us with information on additional solutions or struggles not addressed by our conceptual model. These are shown in the image 5.3.


2.11. Besides the struggles mentioned above, do you have any more concerns when using a software/website regarding accessibility?

Your answer

2.12. How do you think those concerns should be addressed?

Your answer

Figure 5.3: Open Ended Questions

Having written the questions, we turned to [40]'s method of evaluation and used the described parameters to improve them.

Step 3: Evaluating the survey

Before sending out the survey, we wanted to make sure the questions were clear, concise, and unambiguous. Moreover, we wanted to guarantee that we could get information through open-ended questions without overwhelming the user. To address those concerns, we conducted a pilot survey that was sent to two different individuals, one of them had ASD, asking them to detail any difficulties they had as they answered the survey. The results of the pilot survey are documented in Table 5.2 below.

Finally, another change performed during this time was the replacement of the word issue with struggle as the user with ASD warned us that it could be triggering otherwise.

Table 5.2: Pilot Survey Results

<table>
<tr><th colspan="2">Errors Identified</th></tr>
<tr><td>Translation</td><td>Formatting</td></tr>
<tr><th colspan="2">Words/Terms that needed clarification</th></tr>
<tr><td>performing tasks on 2.3</td><td>reading aids/word tracers on 3.14</td></tr>
<tr><td>Customizing the information displayed on 3.15</td><td>Customizing the position of page elements on 3.22</td></tr>
<tr><th colspan="2">Final Questions</th></tr>
<tr><td colspan="2">Missing solutions? No
Time spent? 10 min
Good clarification on survey purposes? Yes, the survey's purpose is to try to understand the difficulties and methods of compensating for those difficulties that people prefer or do not apply them in future websites or programs
Redundant questions? No, some obvious answers but necessary questions</td></tr>
</table>

The final version of the survey is displayed in the appendix C.

Step 4: Publishing the survey

The fourth and final step was to send out the survey to the maximum number of people we could find. Not only did we have to make sure there were enough answers to have significant results, but we also wanted a significant amount of answers from someone with each of the 3 neurodivergent conditions studied in order to have a valid study.

To reach the maximum population possible, we decided to translate the form from English to Portuguese so we could have both options available. The main method employed to publish the survey was direct messaging, as well as the aid of multiple people who employed the same method to their connections. Other methods employed were the use of social media groups like Discord and WhatsApp, and publications on social media websites like Facebook and Instagram. The survey was opened for answers for a total of 2 weeks.

5.1.2 Survey Results

The answers were submitted directly into an Excel where we developed, through the use of various formulas, a way to process them and calculate the statistics and correlations necessary for our work. In total, we collected exactly 100 answers and the general statistics are displayed in figure 5.4. From the total responses, 52 identified as men, 44 as women and 4 as Non-Binary. The biggest age range we obtained was between 18 and 24 with a total of 38 answers, followed by 25 to 34 with 32 answers and 45 to 54 with 16 answers. Through the gender and age distribution, we are able to conclude that our survey was able to reach a broad audience and thus the results are likely to relate to a broader audience and not just a specific user profile.

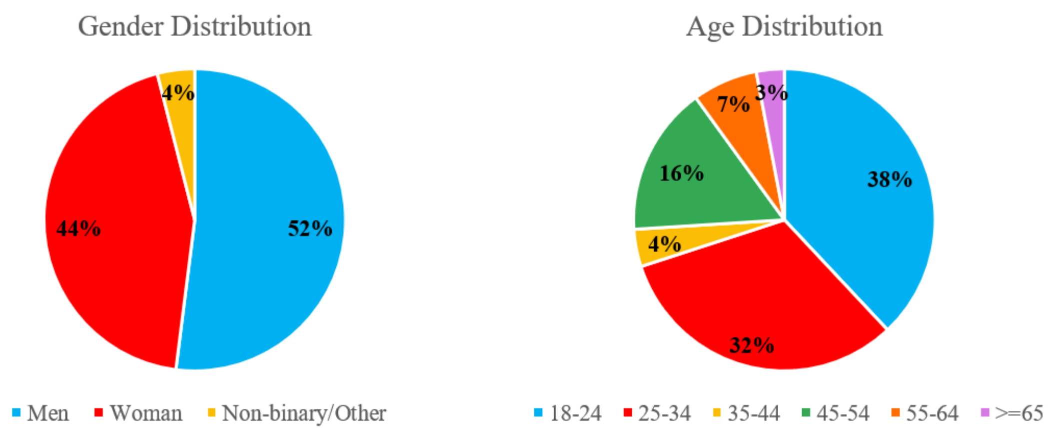


Figure 5.4: Gender and Age Analysis

Finally, we had 63 answers from people who didn't have any neurodivergent condition and 37 answers from people who had it.

Although we had answers from people with more than one condition, we managed to have a significant amount of answers from each condition studied, with a total of 11 answers from someone with Dyslexia, 12 answers from someone with ASD and 20 answers from someone with ADHD. We also obtained 11 answers from people with other neurodivergent conditions besides the 3 mentioned. A few of the additional neurodivergent conditions mentioned in different answers included Anxiety, Depression, Obsessive Compulsive Disorder and Complete Agenesis of the Corpus Callosum.

Since we included the option of self-diagnosis, not all the answers obtained were from official diagnosis. Of the people with Dyslexia, 8 had an official diagnosis. Of the ones with ASD, 9 had an official diagnosis. Finally, of everyone that had ADHD, 10 had an official diagnosis. These results are displayed in figure 5.5.

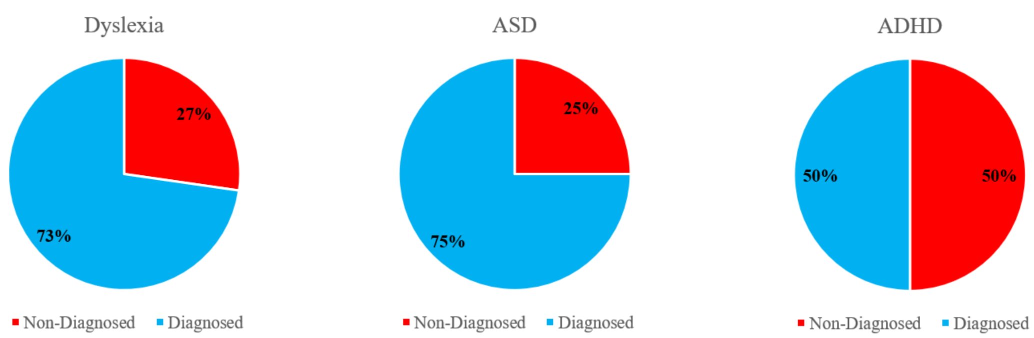


Figure 5.5: Diagnosis Analysis

The survey included both open-ended and multiple-choice questions. We decided to first analyse all the multiple-choice answers obtained. For each question, the respondents had to pick a rating from 1 to 5 from 1 as the least favorable and 5 as the most favorable, following the Likert scale.

As a first analysis, we performed a comparison between the answers from the following groups: Dyslexia, ASD, ADHD, Neurotypical (which includes everyone that answered "no" to question 1.3 "Do you have any Neurodivergent Conditions?") and Neurodivergent (which includes everyone that answer "yes" to the question 1.3). Note that since a person can have multiple conditions, in those cases the answer was counted repeatedly for each individual statistic that accommodates them. For instance, if someone has Dyslexia and ASD, then their answer was taken into account for the statistics for Dyslexia, ASD and Neurodivergent.

5.1.2.1 Section 2 Software and Website struggles: Analysis

We began our analysis with the results of Section 2, which deals with questions related to issues neurodivergent users feel when using a software or website. Figure 5.6 illustrates what concepts will be covered with the questions from this section.

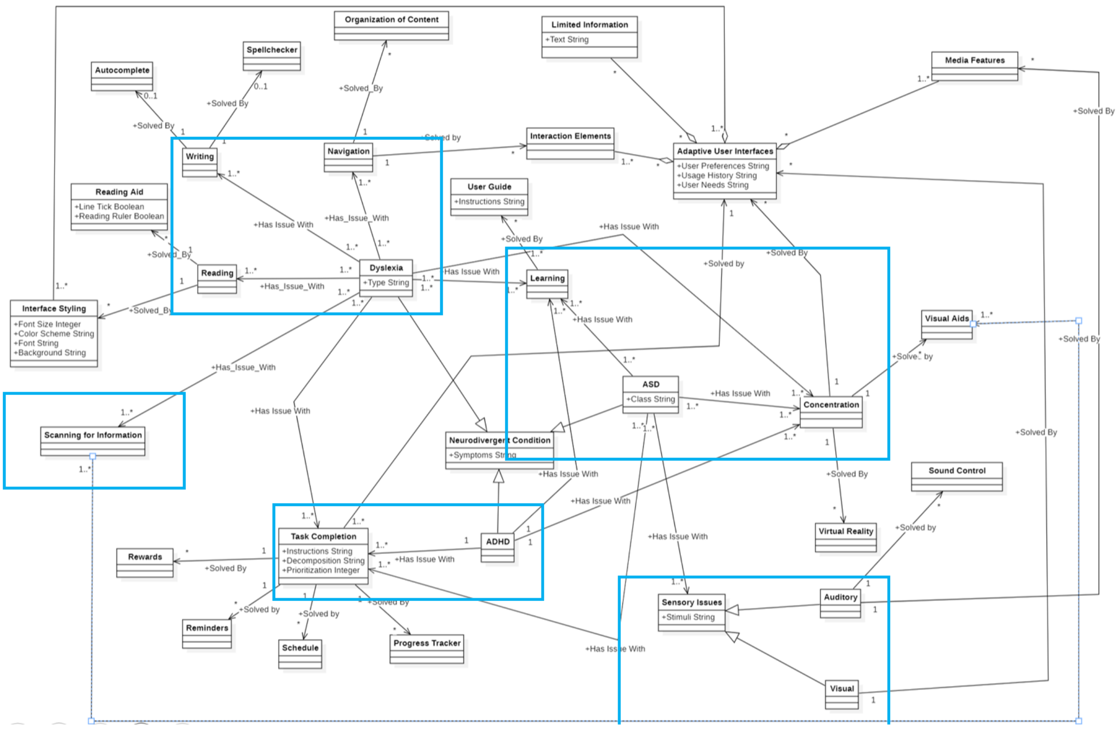


Figure 5.6: Section 2 Concepts

We employed a thorough comparison between the average ratings of each group mentioned for each question answered as it is displayed in figure 5.7.

In the following subsections, we will look at each question from section 2 (Software and Website struggles) individually and analyse the results based on the plots generated

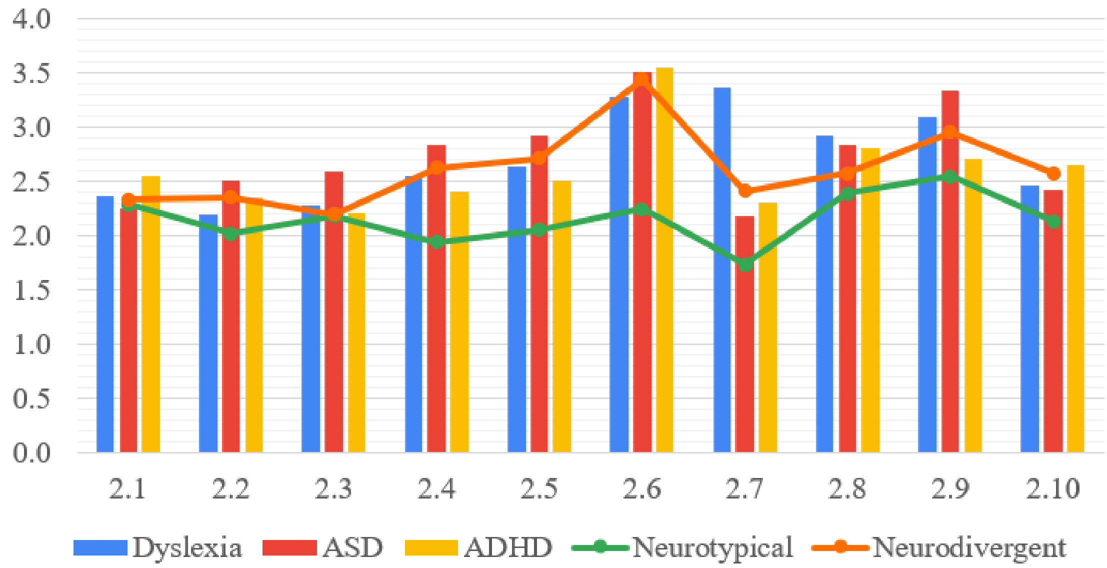


Figure 5.7: Section 2 Average Ratings

above, as well as explain the conclusions taken from that data.

Question 2.1. When using a software/website, how frequently do you struggle with poor readability?

As it is shown in Figure 5.8, the results for this topic showed a little discrepancy between all the population groups, as the average rating for Neurotypicals was the same for Neurodivergents, with a rating of 2.3. The highest average accounted was from people with ADHD which had an average rating of 2.6, followed by Dyslexia with an average of 2.4 and ASD with an average of 2.3.

These ratings showed that most people tend to rarely struggle with poor readability, although people with ADHD tend to sometimes struggle with it.

Question 2.2. When using a software/website, how frequently do you struggle with comprehending what is written?

Figure 5.9 illustrates the answer distribution for the question. The average rating for Neurotypicals was 2.0 which did not deviate much from the average rating of Neurodivergents of 2.4. The group with the highest average rating was ASD, which had an average rating of 2.5, followed by ADHD with an average of 2.4, and Dyslexia with 2.2.

We concluded from these ratings that most people tend to rarely struggle with comprehending what is written, although people with ASD tend to sometimes struggle with it.

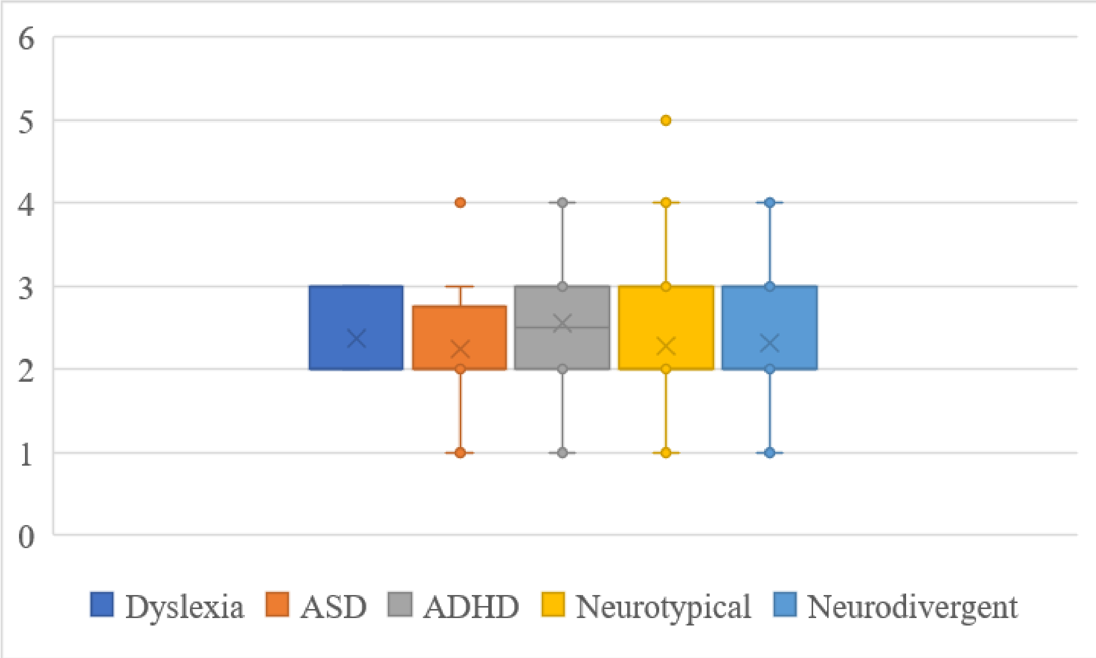


Figure 5.8: Boxplot Graph - Question 2.1

Question 2.3. When using a software/website, how frequently do you struggle with performing tasks?

As is shown in the figure 5.10 the results for this topic showed little discrepancy between all the population groups, as the average rating for Neurotypicals was the same for Neurodivergents, with a rating of 2.2. The highest average rating accounted was from people with ASD which had an average rating of 2.6, followed by Dyslexia with an average of 2.3, and ADHD with 2.2.

These ratings showed that most people tend to rarely struggle with performing tasks, although people with ASD tend to sometimes struggle with it.

Question 2.4. When using a software/website, how frequently do you struggle with visual stimuli (e.g., flashing images)?

The figure in 5.11 illustrates the answer distribution for the question. The average rating for Neurotypicals was 1.9 which deviated by 0.7 from the average rating of Neurodivergents of 2.6. The group with the highest average rating was ASD, which had an average rating of 2.8. For Dyslexia, the average rating was 2.5 and for ADHD, the average rating was 2.4.

We concluded from these ratings that most people with a Neurodivergent condition tend to sometimes struggle with visual stimuli. On the other hand, people without any Neurodivergent condition rarely struggle with it.

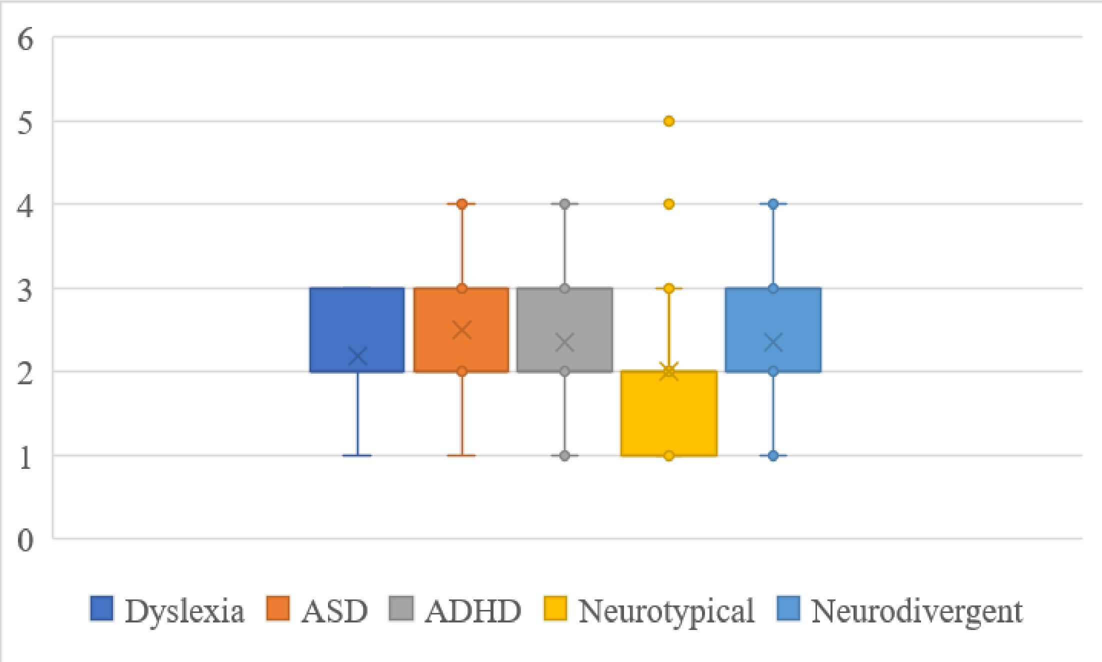


Figure 5.9: Boxplot Graph - Question 2.2

Question 2.5. When using a software/website, how frequently do you struggle with auditory stimuli (e.g., loud sounds)?

As is shown in the figure 5.12 the results for this topic showed a significant difference between the ratings from Neurodivergents and Neurotypicals, with the average rating

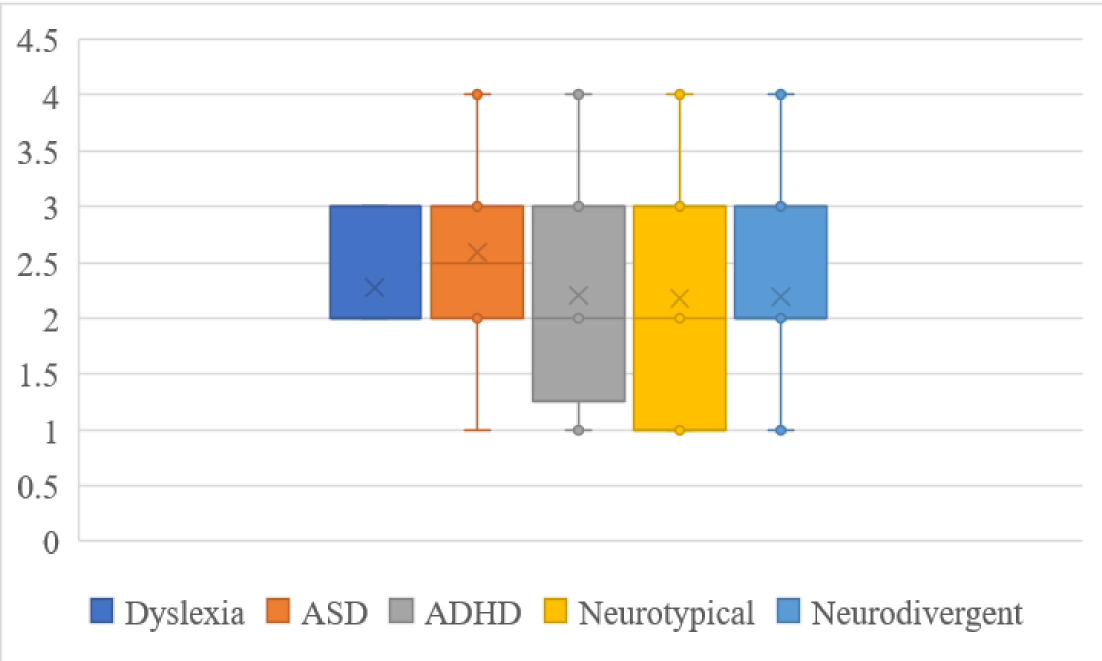


Figure 5.10: Boxplot Graph - Question 2.3

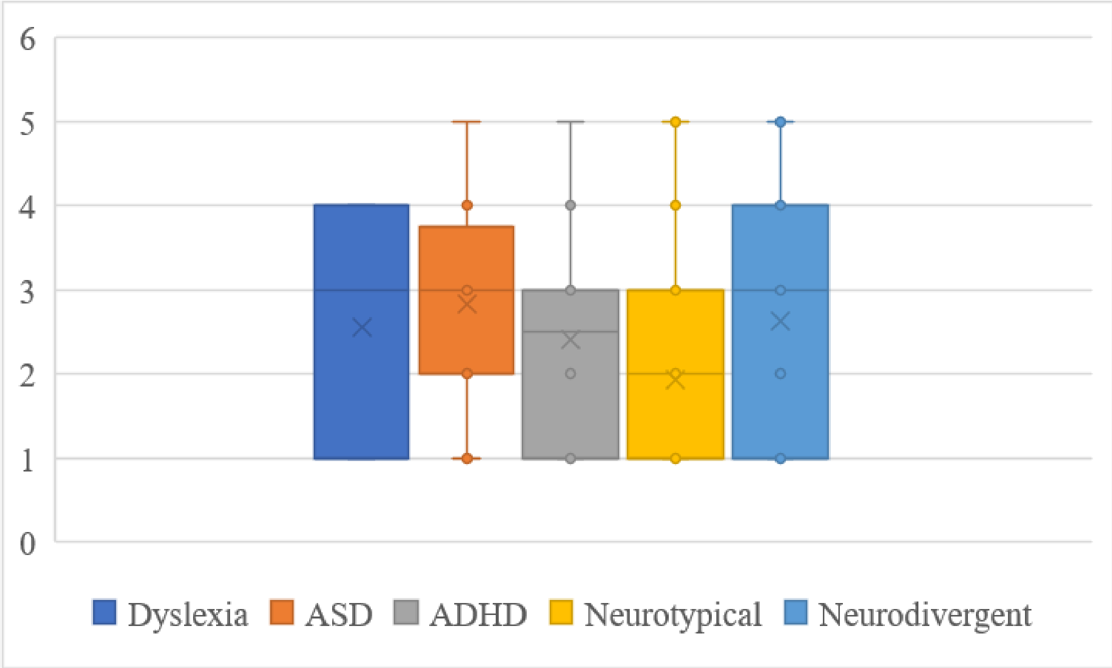


Figure 5.11: Boxplot Graph - Question 2.4

from the first as 2.0, and the average rating from the latter as 2.7. The highest average rating accounted was from people with ASD who in total had an average rating of 2.9. For Dyslexia the average rating was 2.6 and for ADHD was 2.5.

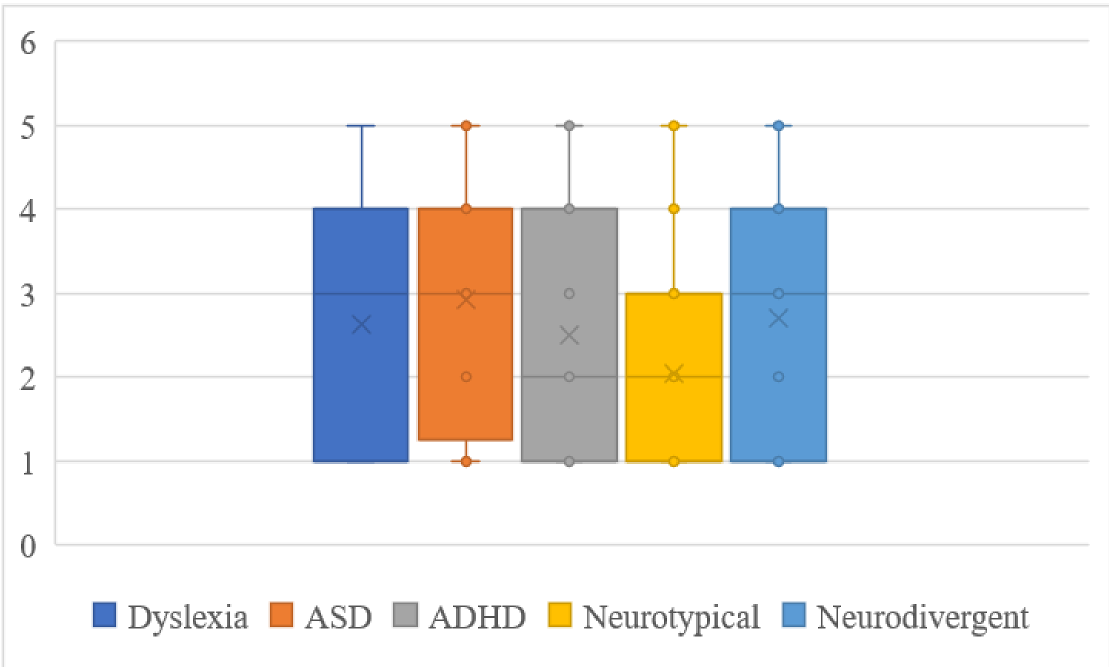


Figure 5.12: Boxplot Graph - Question 2.5

These ratings showed that most people with a Neurodivergent condition tend to sometimes struggle with auditory stimuli. On the other hand, people without any

Neurodivergent condition rarely struggle with it.

Question 2.6. When using a software/website, how frequently do you struggle with concentration?

The figure in 5.13 illustrates the answer distribution for the question. The average rating for Neurotypicals was 2.2 which deviated by 1.2 from the average rating of Neurodivergents of 3.4. This was by far the biggest discrepancy between values registered for this section. The group with the highest average rating was ADHD, which had an average rating of 3.6. For ASD, the average rating was 3.5 and for Dyslexia, the average rating was 3.3.

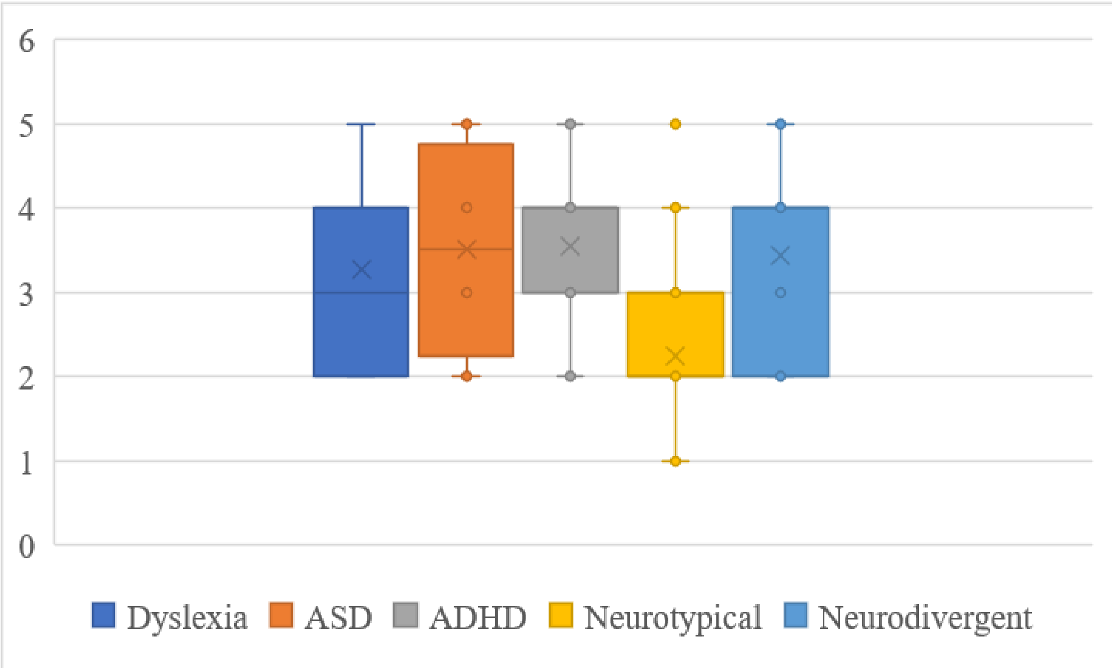


Figure 5.13: Boxplot Graph - Question 2.6

We concluded from these ratings that most people with a Neurodivergent condition tend to sometimes struggle with concentration, although both people with ASD and ADHD tend to often struggle with it. On the other hand, people without any Neurodivergent condition rarely struggle with it.

Question 2.7. When using a software/website, how frequently do you struggle with writing (e.g., spelling, grammar)?

As it is shown in Figure 5.14 the results for this topic showed a significant variance between the ratings from Neurodivergents and Neurotypicals, with the average rating from the first as 1.7, and the average rating from the latter as 2.4. The highest average rating accounted for was from people with Dyslexia who in total had an average rating of 3.4. For ADHD the average rating was 2.3 and for ASD was 2.2.

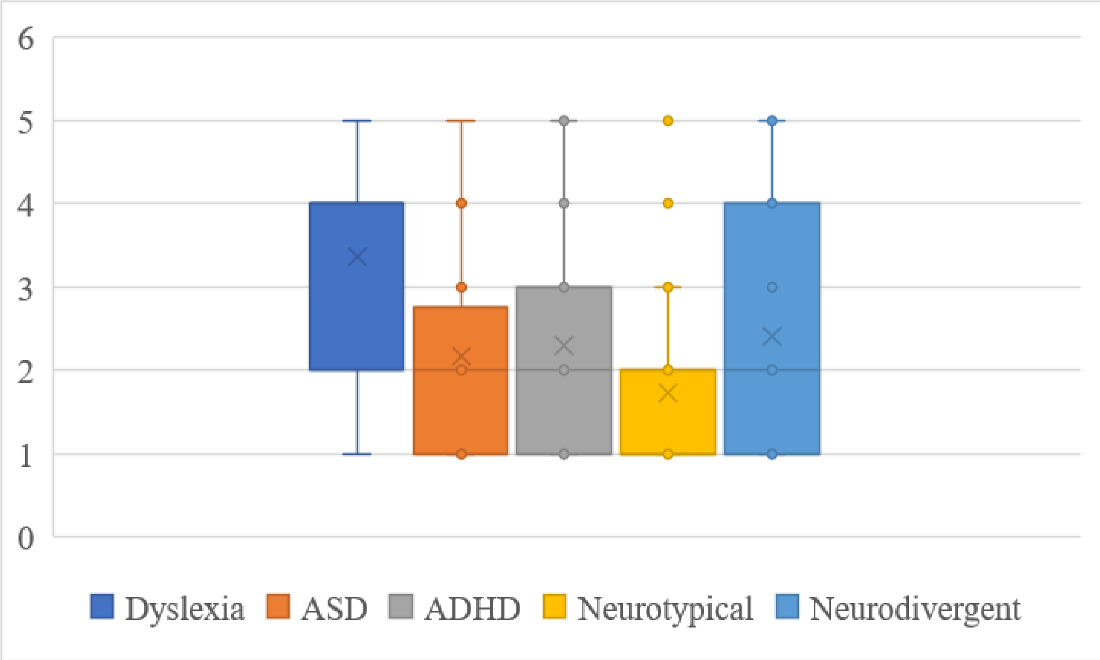


Figure 5.14: Boxplot Graph - Question 2.7

These ratings showed that most people tend to rarely struggle with writing. On the other hand, people with Dyslexia tend to sometimes struggle with it.

Question 2.8. When using a software/website, how frequently do you struggle with learning how to use it?

Figure 5.15 illustrates the answer distribution for the question. The average rating for Neurotypicals was 2.4 which deviated by only 0.2 from the average rating of Neurodivergents of 2.6. The group with the highest average rating was Dyslexia, which had an average rating of 2.9. For ASD, the average rating was 2.8, the same for ADHD.

We concluded from these ratings that most people with a Neurodivergent condition tend to sometimes struggle with learning how to use it. On the other hand, people without any Neurodivergent condition rarely struggle with it.

Question 2.9. When using a software/website, how frequently do you struggle with finding the information you need?

As is shown in Figure 5.16 the results for this topic showed a little variance between the ratings from Neurodivergents and Neurotypicals, with the average rating from the first as 2.5, and the average rating from the latter as 2.9. The highest average rating accounted for was from people with ASD which in total had an average rating of 3.3. For Dyslexia the average rating was 3.1 and for ADHD was 2.7.

These ratings showed that most people tend to sometimes struggle with finding the information they need.

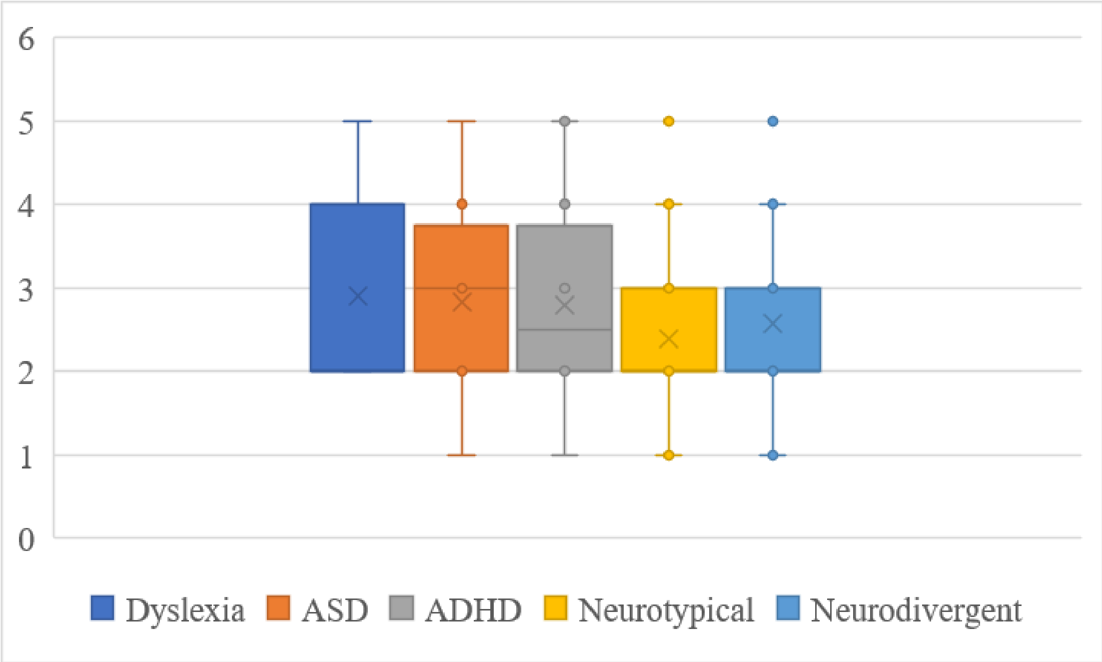


Figure 5.15: Boxplot Graph - Question 2.8

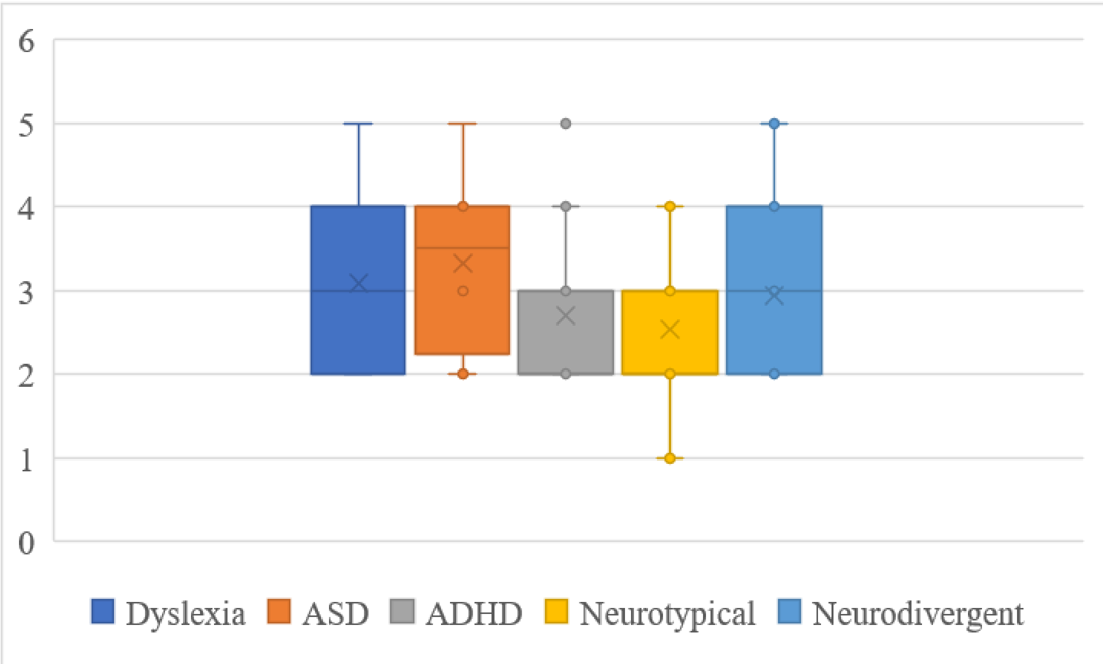


Figure 5.16: Boxplot Graph - Question 2.9

Question 2.10. When using a software/website, how frequently do you struggle with following instructions?

Figure 5.17 illustrates the answer distribution for the question. The average rating for Neurotypicals was 2.1 which deviated by only 0.5 from the average rating of Neurodivergents of 2.6. The group with the highest average rating was ADHD, which had an average rating of 2.7. For Dyslexia, the average rating was 2.5, and for ADHD 2.4.

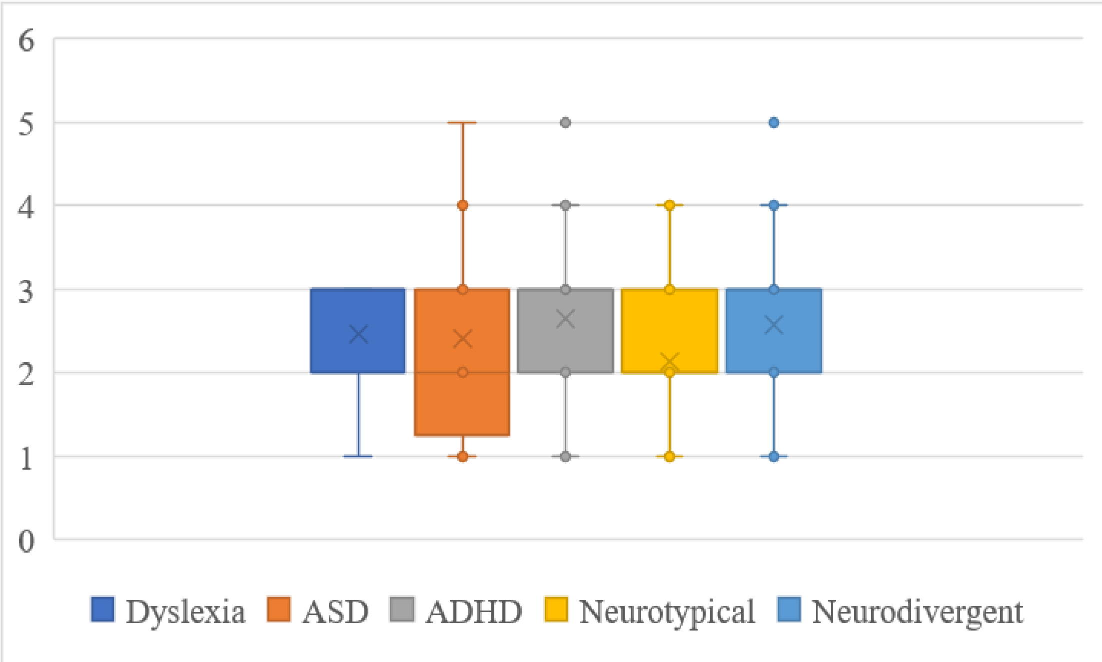


Figure 5.17: Boxplot Graph - Question 2.10

We concluded from these ratings that most people with a Neurodivergent condition tend to sometimes struggle with following instructions. On the other hand, people without any Neurodivergent condition rarely struggle with it.

5.1.2.2 Section 3 Software Requirements: Analysis

Section 3 (Software Requirements) deals with questions related to specific software requirements that accommodate the struggles discussed in the previous section. Figure 5.18 illustrates what concepts were evaluated with the questions from this section.

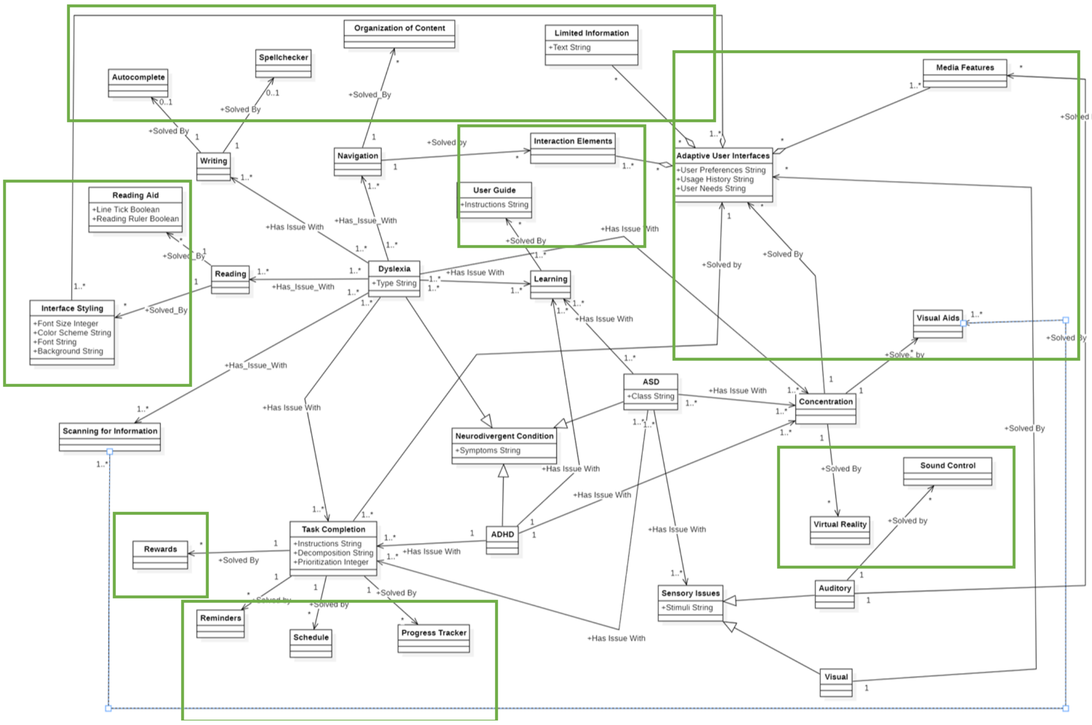


Figure 5.18: Section 3 Concepts

We generated graphs that could help us compare the averages from each group for each question from section 3, and those results are displayed in Figure 5.19.

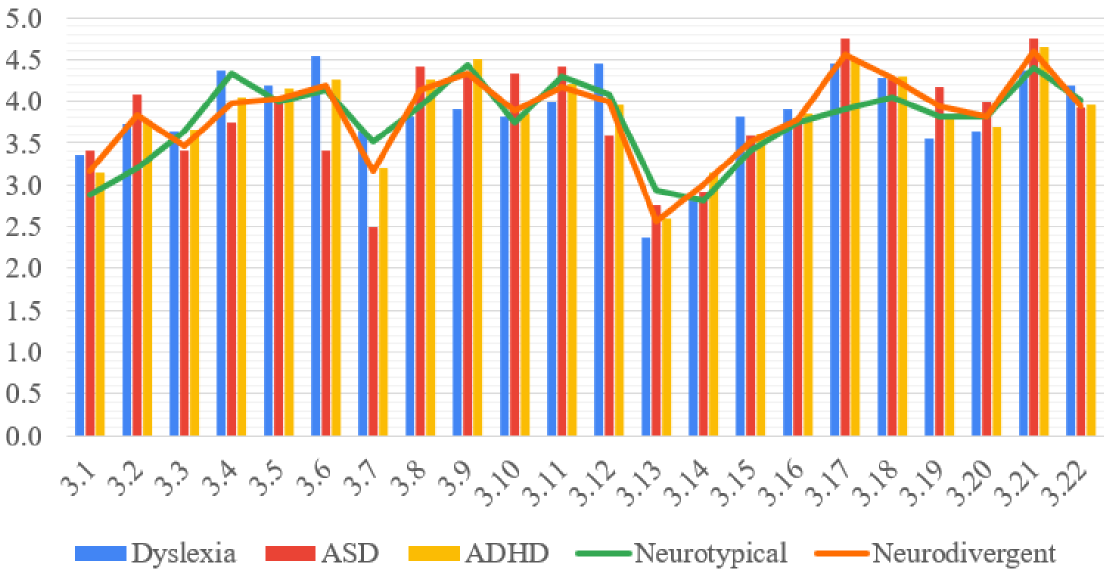


Figure 5.19: Section 3 Average Ratings

In the following subsections, we will look at each question from section 3 individually and analyse the results based on the plots generated above, as well as explain the conclusions taken from that data.

Question 3.1. A colored background and contrasting bold letters are easier to read.

The figure in 5.20 illustrates the answer distribution for the question. The average rating for Neurotypicals was 2.9 which deviated only by 0.3 from the average rating of Neurodivergents of 3.2. The group with the highest average rating was ASD and Dyslexia, which had an average rating of 3.4, followed by ADHD with an average of 3.2.

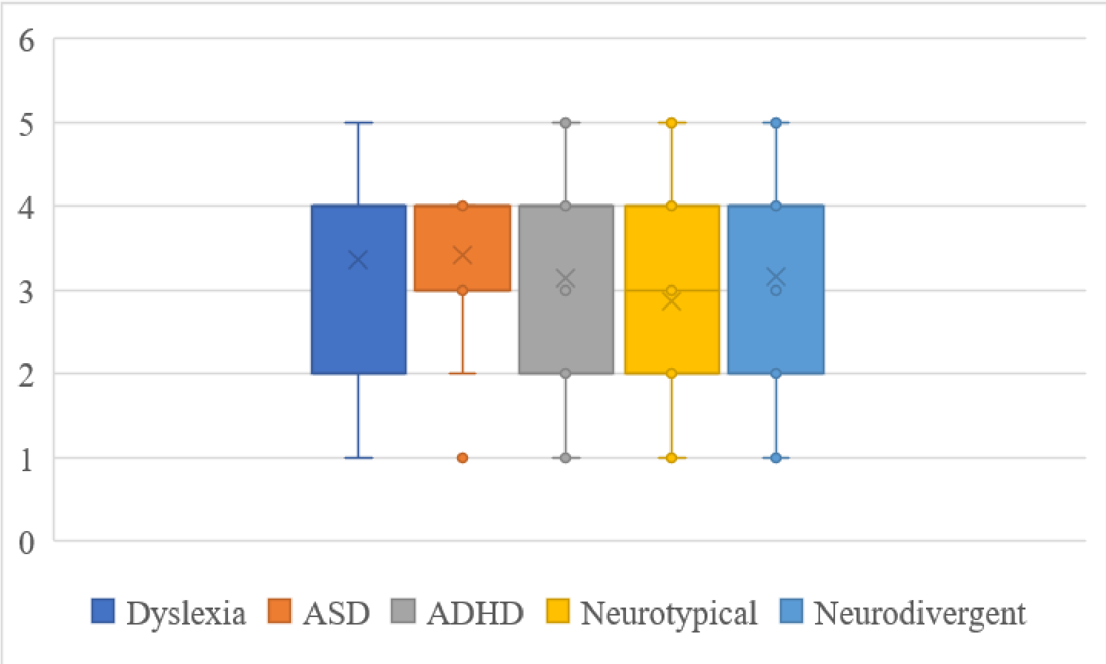


Figure 5.20: Boxplot Graph - Question 3.1

We concluded from these results that most people are indifferent to a colored background with contrasting bold letters.

Question 3.2. A reward at the end of the task is effective in helping with task completion.

As is shown in Figure 5.21 the results for this topic showed some discrepancy between all the population groups, as the average rating for Neurotypicals was 3.2 and Neurodivergents had an average rating of 3.8. The highest average accounted was from people with ASD with an average rating of 4.1, followed by ADHD with an average rating of 3.8 and Dyslexia with an average of 3.7.

These ratings showed that most people with a Neurodivergent condition tend to agree that a reward at the end of the task is effective in helping with task completion, although people without any condition tend to be indifferent towards it.

Question 3.3. Alarm reminders are effective in helping with task completion.

Figure 5.22 illustrates the answer distribution for the question. The average rating for Neurodivergents was 3.5 which deviated only by 0.1 from the average rating of Neurotypicals

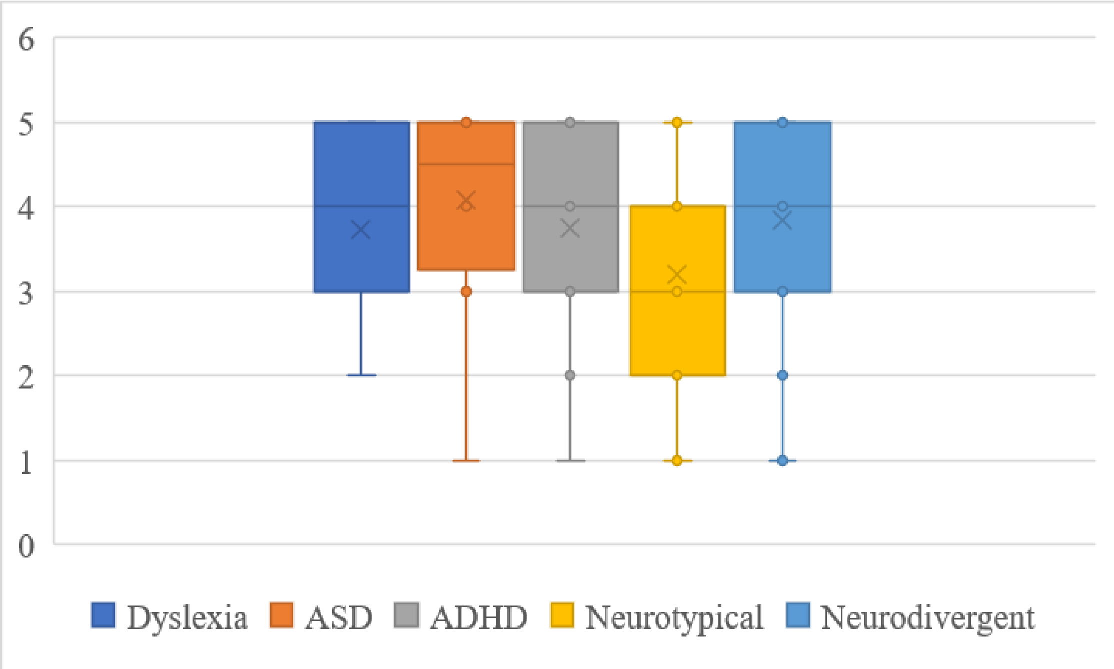


Figure 5.21: Boxplot Graph - Question 3.2

of 3.6. The group with the highest average rating was ADHD, which had an average rating of 3.7, followed by Dyslexia with an average of 3.6, and finally by ASD with an average rating of 3.4.

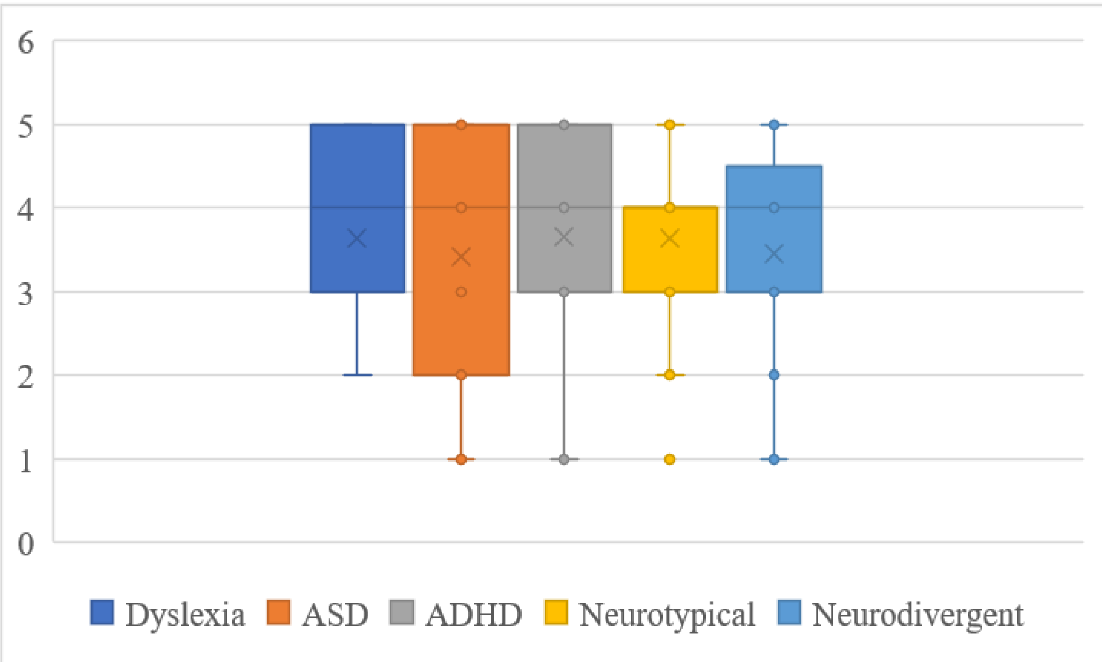


Figure 5.22: Boxplot Graph - Question 3.3

We concluded from these results that most people agree that alarm reminders are effective in helping with task completion, although on average people with ASD are closer to being indifferent about it.

Question 3.4. An organized schedule is effective in helping with task prioritization.

As it is shown in Figure 5.23 the results for this topic showed some discrepancy between all the population groups, as the average rating for Neurotypicals was 4.3 and Neurodivergents had an average rating of 4.0. The highest average accounted was from people with Dyslexia with an average rating of 4.4, followed by ADHD with an average rating of 4.1 and ASD with an average of 3.8.

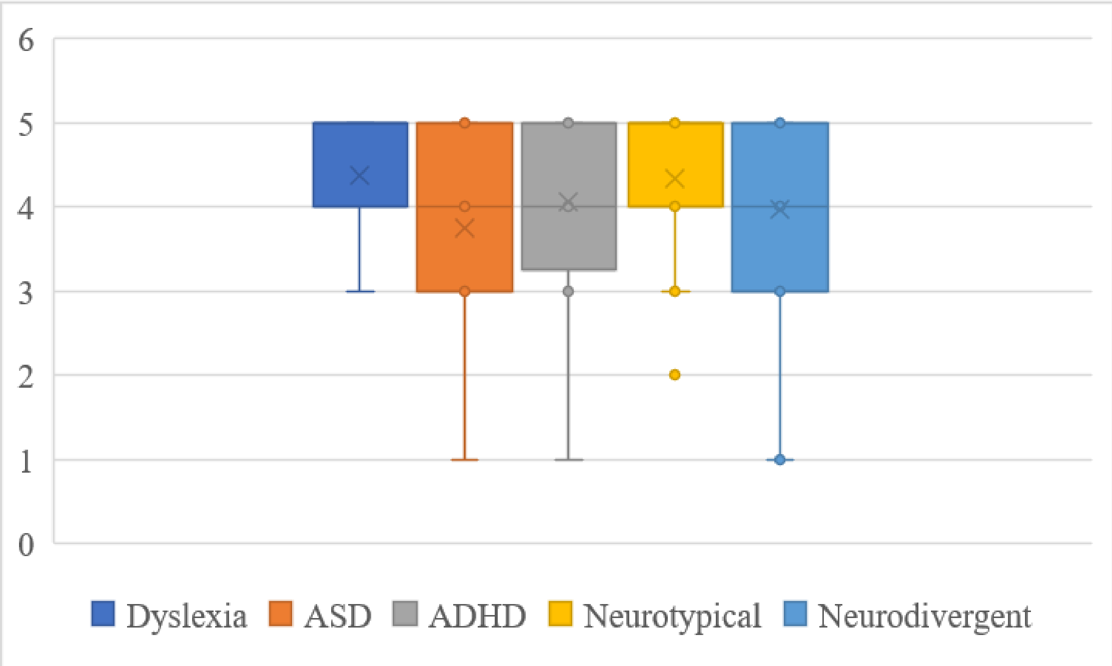


Figure 5.23: Boxplot Graph - Question 3.4

These ratings showed that most people tend to agree that an organized schedule is effective in helping with task prioritization.

Question 3.5. A task progress tracker is effective in helping with task completion.

Figure 5.24 illustrates the answer distribution for the question. The average rating for Neurodivergents was the same as the rating for Neurotypical, which registered an average rating of 4.0. The groups with the highest average rating were ADHD and Dyslexia, which had an average rating of 4.2, followed by ASD with an average of 4.0.

We concluded from these results that most people agree with the statement that "a task progress tracker is effective in helping with task completion".

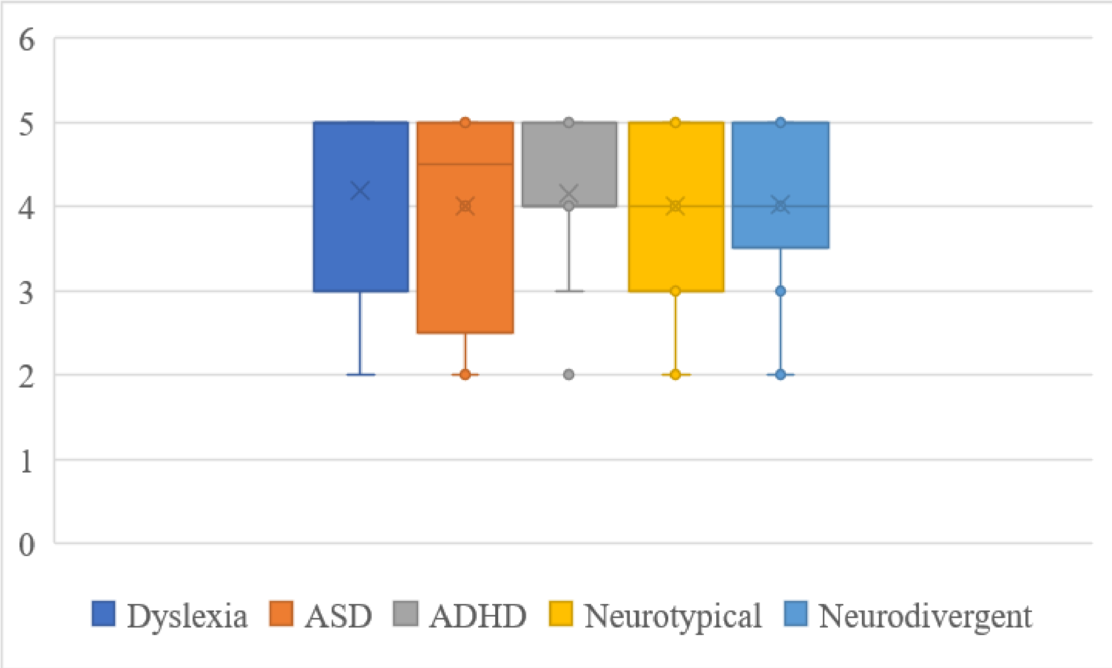


Figure 5.24: Boxplot Graph - Question 3.5

Question 3.6. An automatic spellchecker is effective in helping with writing.

As it is shown in Figure 5.25, the results for this topic showed a little discrepancy between all the population groups, as the average rating for Neurotypicals was 4.1 and Neurodivergents had an average rating of 4.2. The highest average accounted was from people with Dyslexia with an average rating of 4.5, followed by ADHD with an average rating of 4.3 and ASD with an average of 3.4.

These ratings showed that most people tend to agree that an automatic spellchecker is effective in helping with writing, although people with Dyslexia tend to agree strongly with it and people with ASD tend to be indifferent towards it.

Question 3.7. Smart autocomplete is effective in helping with writing.

Figure 5.26 illustrates the answer distribution for the question. The average rating for Neurodivergents was 3.2 which differed only 0.4 from the average rating for Neurotypicals of 3.5. The group with the highest average rating was Dyslexia, which had an average rating of 3.6, followed by ADHD with an average rating of 3.2, and finally ASD with an average of 2.5.

We concluded from these results that although most people with a Neurodivergent condition tend to be indifferent towards the statement that "smart autocomplete is effective in helping with writing", people with Dyslexia tend to agree with it. Most people without any Neurodivergent condition tend to agree with the statement as well.

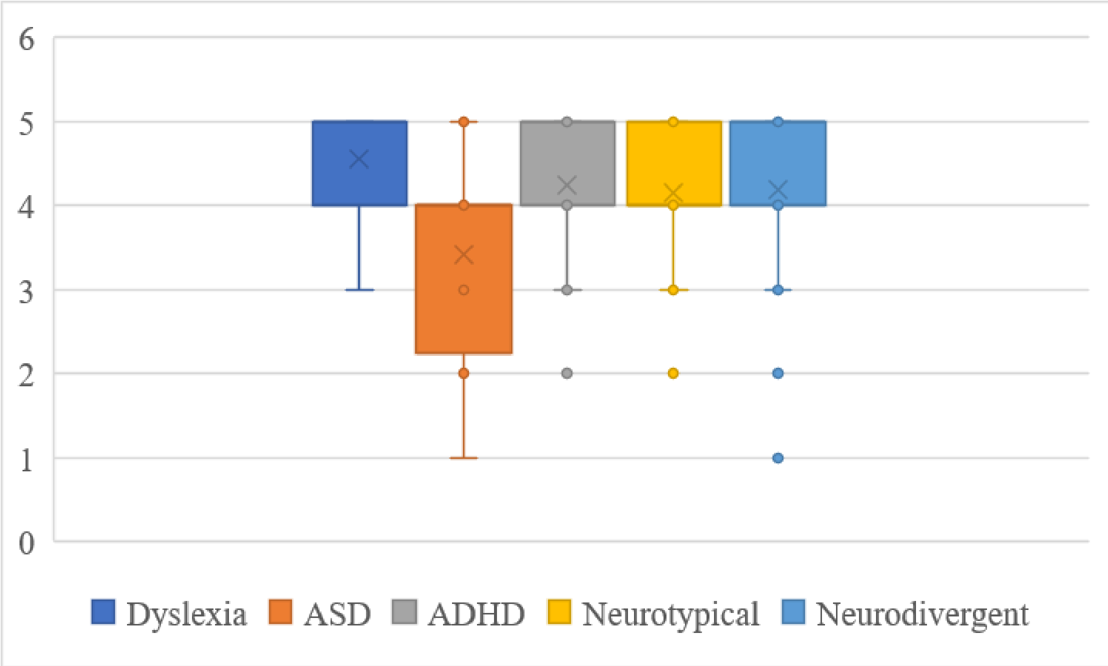


Figure 5.25: Boxplot Graph - Question 3.6

Question 3.8. Avoiding redundant instructions helps with following instructions.

As is shown in Figure 5.27 the results for this topic showed little discrepancy between all the population groups, as the average rating for Neurotypicals was 3.9 and Neurodivergents had an average rating of 4.1. The highest average accounted was from people with ASD with an average rating of 4.4, followed by ADHD with an average rating of 4.3 and Dyslexia with an average of 3.8.

These ratings showed that most people tend to agree that avoiding redundant instructions helps with following instructions.

Question 3.9. Clear and concise writing helps with following instructions.

Figure 5.28 illustrates the answer distribution for the question. The average rating for Neurodivergents was 4.3 which differed only 0.1 from the average rating for Neurotypicals of 4.4. The group with the highest average rating was ADHD, which had an average rating of 4.5, followed by ASD with an average rating of 4.3, and finally Dyslexia with an average of 3.9.

We concluded from these results that although most people tend to agree with the statement that "clear and concise writing helps with following instructions", people with ASD tend to strongly agree with it.

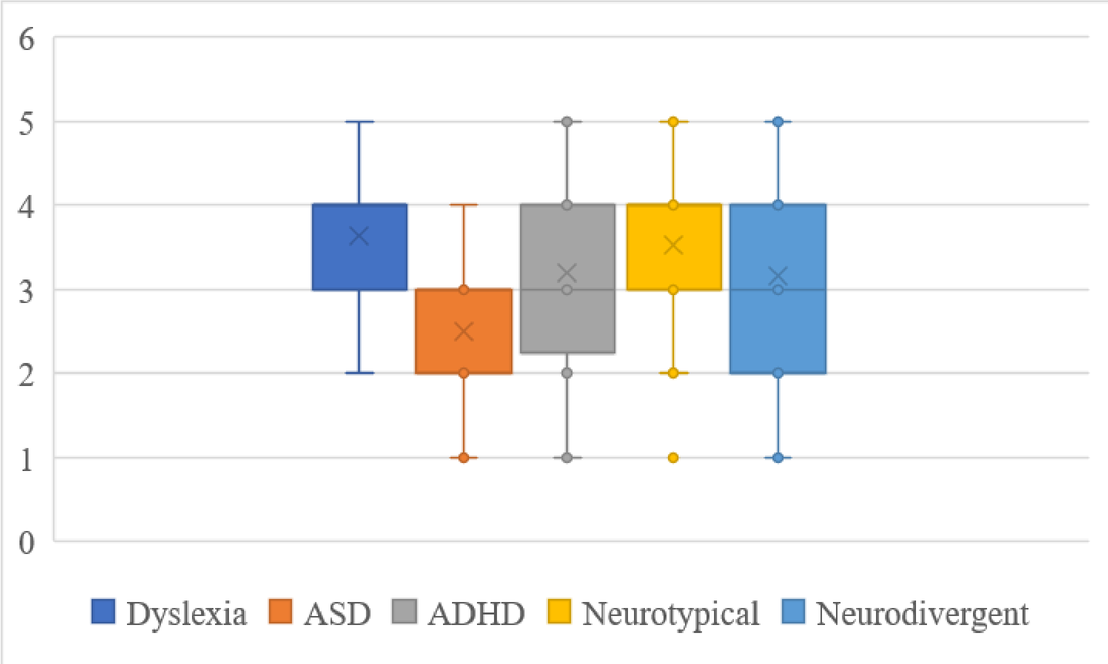


Figure 5.26: Boxplot Graph - Question 3.7

Question 3.10. More detailed information helps with following instructions.

As it is shown in Figure 5.29 the results for this topic showed a little discrepancy between all the population groups, as the average rating for Neurotypicals was 3.7 and Neurodivergents had an average rating of 3.9. The highest average accounted was from people with ASD with an average rating of 4.3, followed by ADHD with an average rating of 3.9 and Dyslexia with an average of 3.8.

These ratings showed that most people tend to agree that more detailed information helps with following instructions.

Question 3.11. Visual aids (e.g., illustrations) help with finding the information you need.

Figure 5.30 illustrates the answer distribution for the question. The average rating for Neurodivergents was 4.2 which differed only 0.1 from the average rating for Neurotypicals of 4.3. The group with the highest average rating was ASD, which had an average rating of 4.4, followed by ADHD with an average rating of 4.2, and finally Dyslexia with an average of 4.0.

We concluded from these results that most people tend to agree with the statement that "Visual aids (e.g., illustrations) help with finding the information you need".

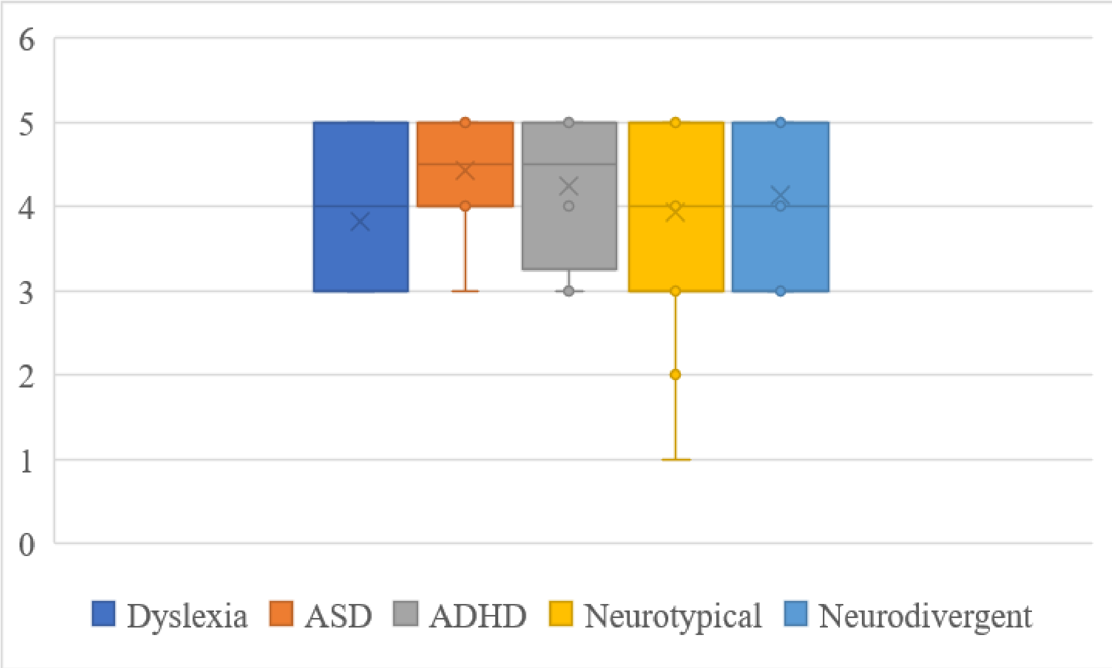


Figure 5.27: Boxplot Graph - Question 3.8

Question 3.12. Limiting the amount of text is effective in helping with concentration.

As it is shown in Figure 5.31 the results for this topic showed little discrepancy between all the population groups, as the average rating for Neurotypicals was 4.1 and Neurodivergents had an average rating of 4.0. The highest average accounted was from people with Dyslexia with an average rating of 4.5, followed by ADHD with an average rating of 4.0 and ASD with an average of 3.6.

These ratings showed that most people tend to agree that limiting the amount of text is effective in helping with concentration, although people with Dyslexia tend to strongly agree with that affirmation.

Question 3.13. Virtual Reality software/websites are effective in helping with concentration.

Figure 5.32 illustrates the answer distribution for the question. The average rating for Neurodivergents was 2.6 which differed 0.3 from the average rating for Neurotypicals of 2.9. The group with the highest average rating was ASD, which had an average rating of 2.8, followed by ADHD with an average rating of 2.6, and finally Dyslexia with an average of 2.4.

We concluded from these results that most people tend to be indifferent towards the statement that "Virtual Reality software/websites are effective in helping with concentration", except for people with Dyslexia who tend to disagree with that statement.

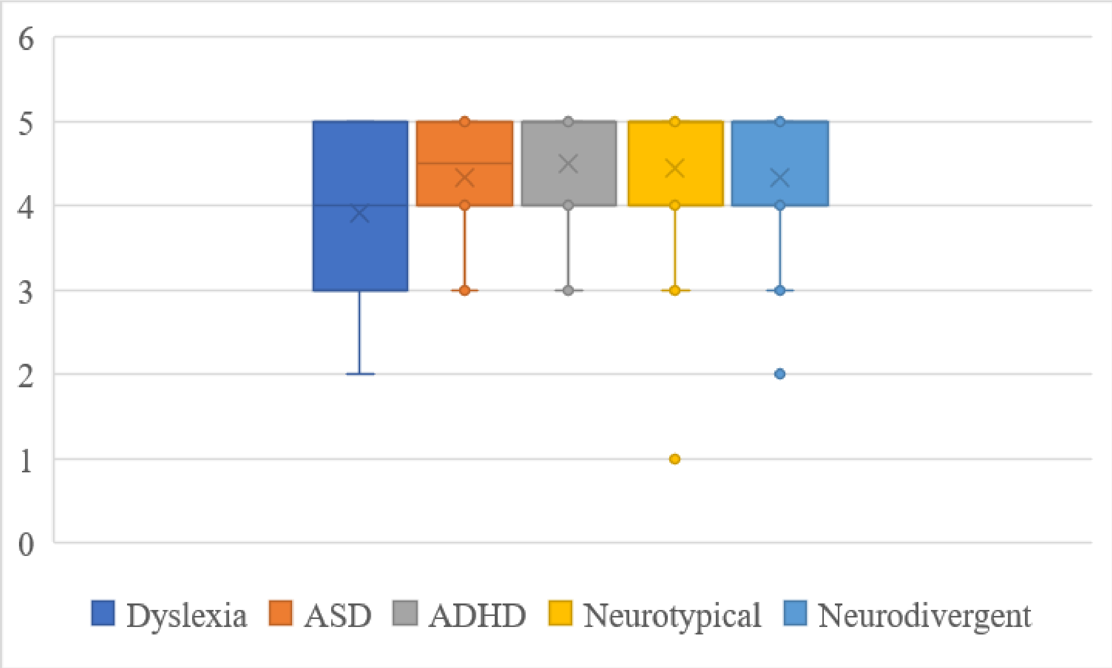


Figure 5.28: Boxplot Graph - Question 3.9

Question 3.14. Reading aids (e.g., a word tracer like in karaoke) are effective in helping with reading.

As is shown in Figure 5.33 the results for this topic showed little discrepancy between all the population groups, as the average rating for Neurotypicals was 2.8 and Neurodivergents had an average rating of 3.0. The highest average accounted was from people with ADHD with an average rating of 3.2, followed by ASD with an average rating of 2.9 and Dyslexia with an average of 2.8.

These ratings showed that most people tend to agree that reading aids (e.g., a word tracer like in karaoke) are effective in helping with reading.

Question 3.15. Customizing the information displayed (e.g., using a filter) is effective in helping with concentration.

Figure 5.34 illustrates the answer distribution for the question. The average rating for Neurodivergents was 3.5 which differed 0.1 from the average rating for Neurotypicals of 3.4. The highest average accounted was from people with Dyslexia with an average rating of 3.8, followed by ASD and ADHD with an average rating of 3.6.

We concluded from these results that most people tend to agree with the statement that "Customizing the information displayed (e.g., using a filter) is effective in helping with concentration", except for people without any condition that tends to be indifferent to that statement.

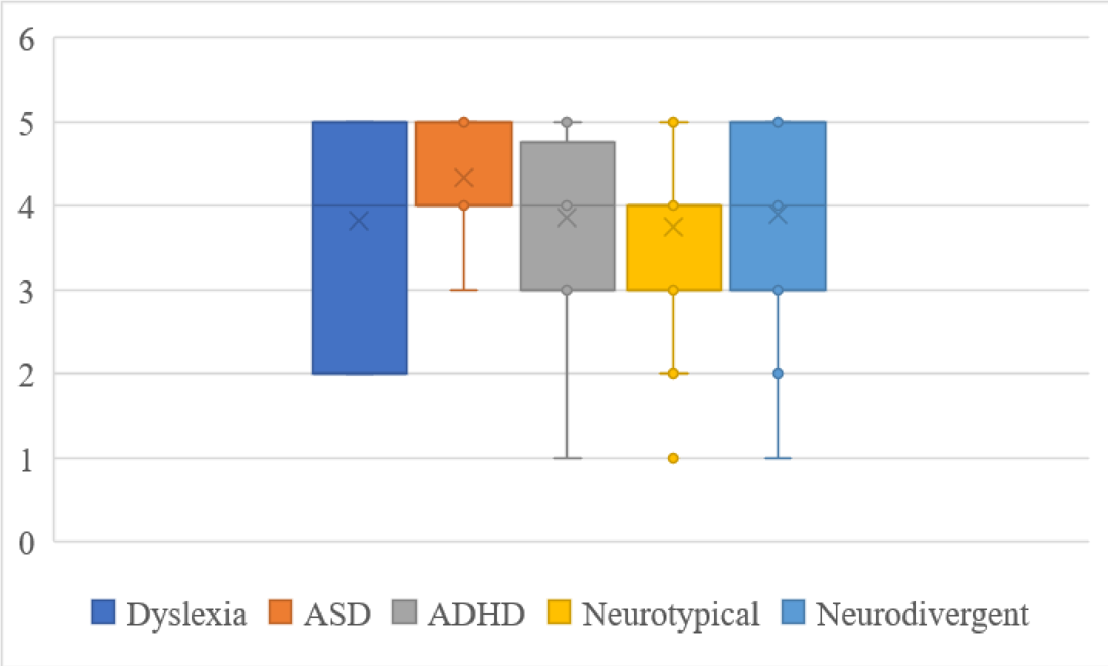


Figure 5.29: Boxplot Graph - Question 3.10

Question 3.16. Visual illustrations are effective in helping with concentration.

As shown in Figure 5.35 the results for this topic showed little discrepancy between all the population groups, as the average rating for Neurotypicals was 3.7 and Neurodivergents had an average rating of 3.8. The highest average accounted was from people with ADHD

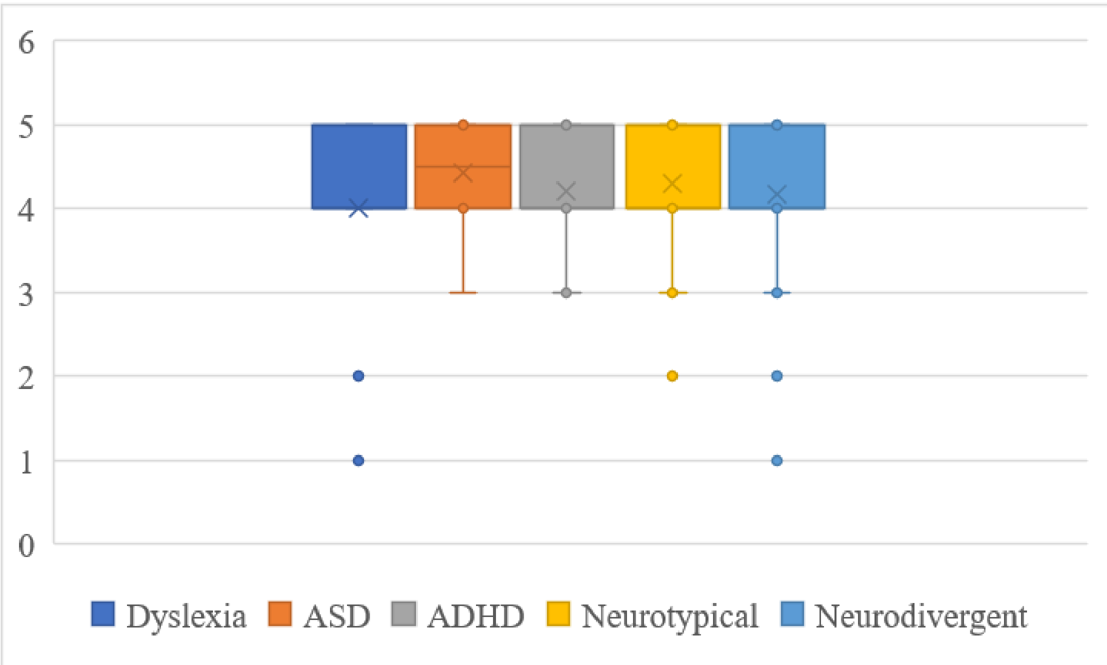


Figure 5.30: Boxplot Graph - Question 3.11

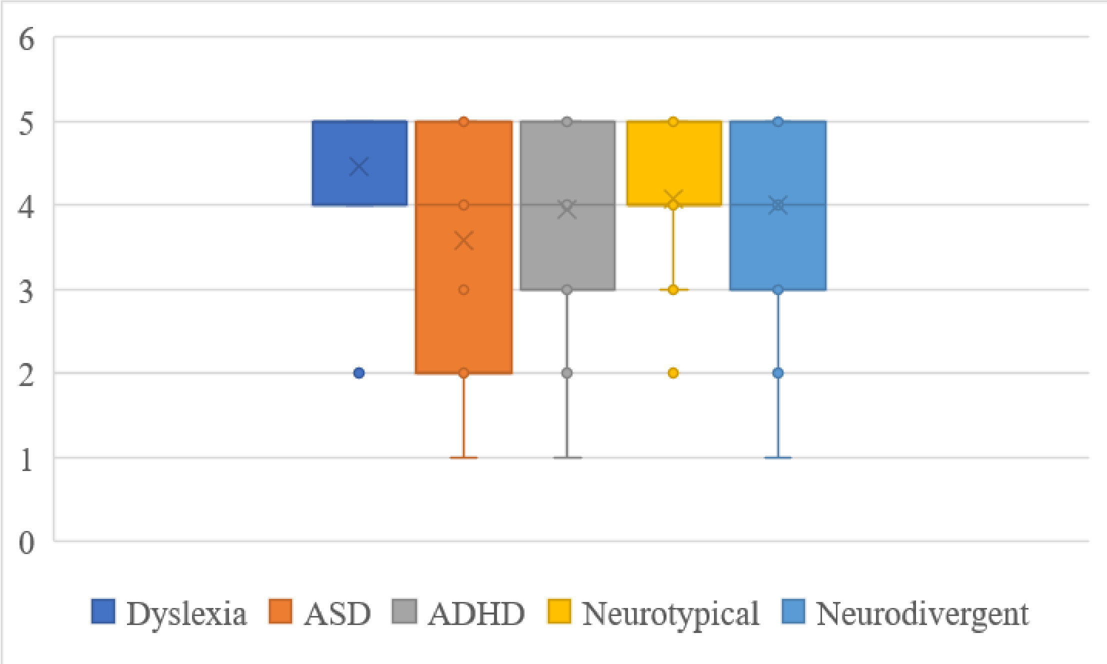


Figure 5.31: Boxplot Graph - Question 3.12

and Dyslexia with an average rating of 3.9, followed by ASD with an average rating of 3.8.

These ratings showed that most people tend to agree that Visual illustrations are effective in helping with concentration.

Question 3.17. Sound customization (e.g., volume control) is effective in helping with auditory overstimulation.

Figure 5.36 illustrates the answer distribution for the question. The average rating for Neurodivergents was 4.6 which differed 0.7 from the average rating for Neurotypicals of 3.9. The highest average accounted was from people with ASD with an average rating of 4.8, followed by Dyslexia and ADHD with an average rating of 4.5.

We concluded from these results that most people with a Neurodivergent condition tend to strongly agree with the statement that "Sound customization (e.g., volume control) is effective in helping with auditory overstimulation", whereas people without any condition tend to only agree with that statement.

Question 3.18. Visual customization (e.g., brightness control) is effective in helping with visual overstimulation.

As shown in Figure 5.37 the results for this topic showed little discrepancy between all the population groups, as the average rating for Neurotypicals was 4.0 and Neurodivergents had an average rating of 4.3. All three studied Neurodivergent conditions showed the same average rating of 4.3.

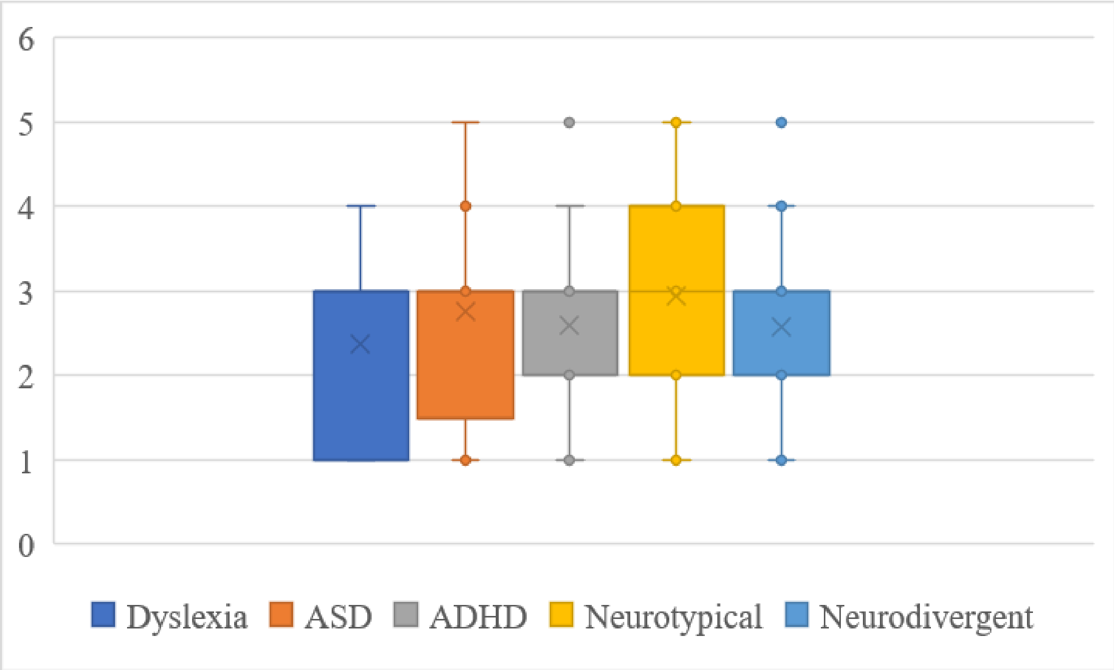


Figure 5.32: Boxplot Graph - Question 3.13

These ratings showed that most people tend to agree that Visual customization (e.g., brightness control) is effective in helping with visual overstimulation.

Question 3.19. A descriptive user guide helps with software/website learning.

Figure 5.38 illustrates the answer distribution for the question. The average rating for Neurodivergents was 3.9 which differed only by 0.1 from the average rating for Neurotypicals of 3.8. The highest average accounted was from people with Dyslexia with an average rating of 4.2, followed by ADHD with an average rating of 3.8, and finally by ASD with an average of 3.5.

We concluded from these results that most people tend to agree with the statement that "A descriptive user guide helps with software/website learning".

Question 3.20. More detailed instructions help with software/website learning.

As shown in Figure 5.39 the results for this topic showed no discrepancy between all the population groups, as the average rating for Neurotypicals was 3.8 and Neurodivergents had an average rating of 3.8 as well. The highest average rating calculated was 4.0 which belonged to people with ASD, afterwards was ADHD which had an average rating of 3.7 and Dyslexia with 3.6.

These ratings showed that most people tend to agree that more detailed instructions help with software/website learning.

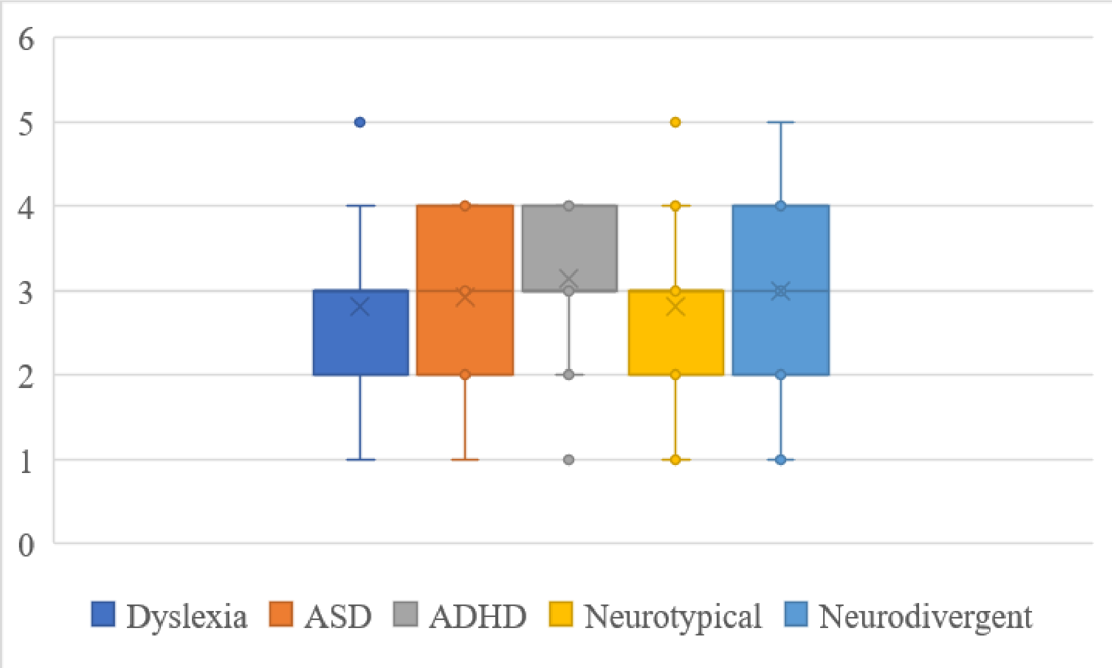


Figure 5.33: Boxplot Graph - Question 3.14

Question 3.21. Clear organization of elements helps with page navigation.

Figure 5.40 illustrates the answer distribution for the question. The average rating for Neurodivergents was 4.6 which differed only by 0.2 from the average rating for Neurotypicals of 4.4. The highest average accounted was from people with ASD with an average rating of 4.8, followed by ADHD with an average rating of 4.7 and finally by ASD with an average of 4.4.

We concluded from these results that most people with a Neurodivergent condition tend to strongly agree with the statement that "Clear organization of elements helps with page navigation", except for people with Dyslexia who just tend to agree with it. At the same time, most people without any Neurodivergent condition simply agree with the affirmation as well.

Question 3.22. Customizing the position of page elements (e.g., favorites tab) helps with page navigation when using a software/website.

As shown in Figure 5.41 the results for this topic showed little discrepancy between all the population groups, as the average rating for Neurotypicals was 4.0 and Neurodivergents had an average rating of 3.9. The highest average rating calculated was 4.2 which belonged to people with Dyslexia, afterwards was ADHD which had an average rating of 4.0 and ASD with 3.9.

These ratings showed that most people tend to agree that customizing the position of page elements (e.g., favorites tab) helps with page navigation when using a software/website.

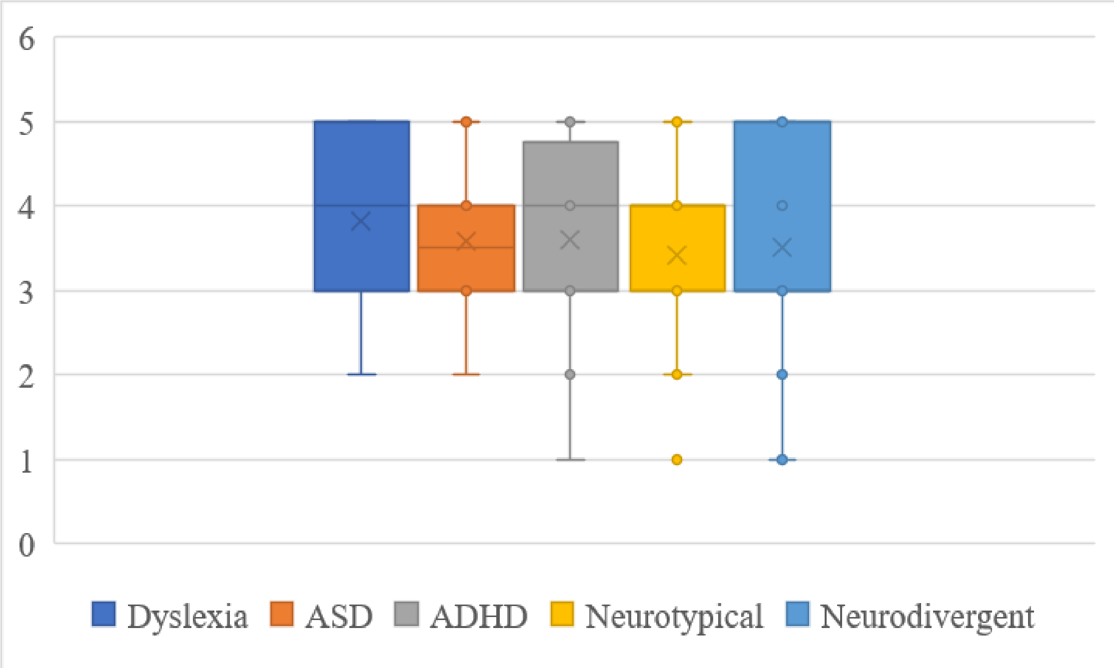


Figure 5.34: Boxplot Graph - Question 3.15

5.1.2.3 Open-Ended Answers: Analysis

The survey included two open-ended questions that asked for any concerns related to software usability that were not covered in the questions described in the previous sections, as well as any suggestions of solutions to implement to solve those concerns. These questions were completely optional, so the number of answers obtained is substantially lower than the number of total participants in the survey.

A total of 44 respondents answered the open-ended questions, which equates to 44 % of the total participants. We generated the pie chart 5.42 for the general statistics of this population, with the age and gender distribution. Of the total respondents, 28 were Neurotypicals and only 16 were Neurodivergent, with 4 having Dyslexia, 8 ASD, and 10 ADHD. This indicated that the results from Neurodivergent were not significant and would not represent Neurodivergency as a whole.

We employed a methodology to analyse the responses by dissecting them into pivotal keywords or phrases that encapsulate the user's intent. Some of the answers were discarded due to not being relevant to the question or study. Subsequently, we consolidated responses sharing similar meanings and conducted statistical analysis on recurring comments.

We organised the results into the different previously discussed groups, and we will delve into the findings in the subsequent sections.

Dyslexia

The table 5.3 presents the suggestions from users with Dyslexia for improving usability features on software/websites. Each row corresponds to a specific suggestion, and the

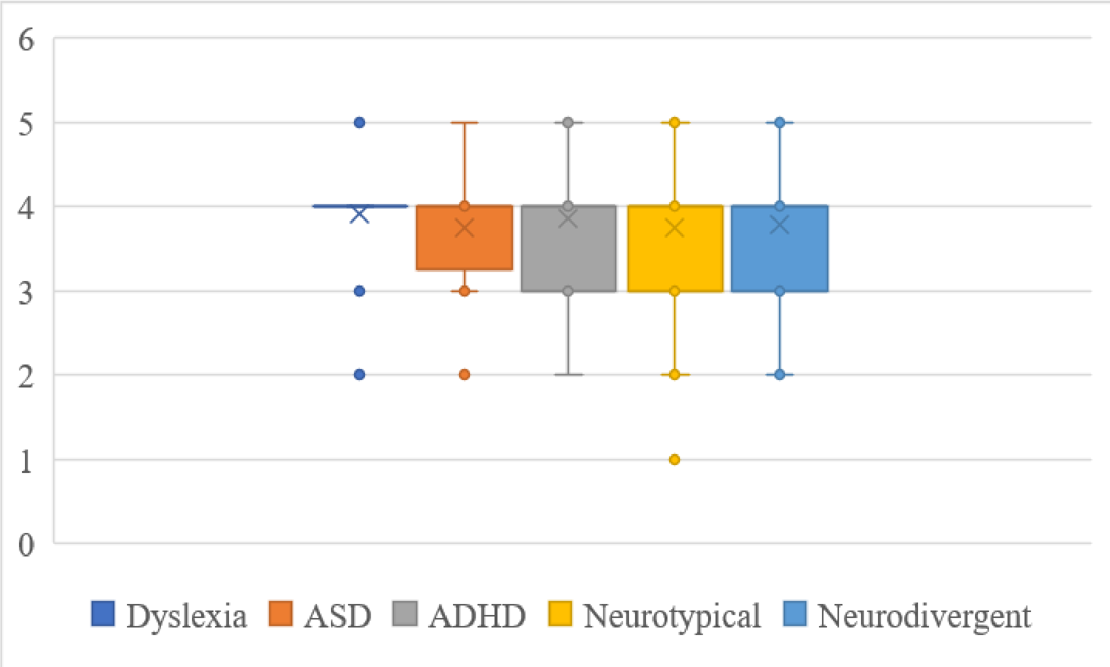


Figure 5.35: Boxplot Graph - Question 3.16

second column indicates the number of user responses advocating for that particular suggestion.

Table 5.3: Answers from Users with Dyslexia

Suggestion	**Number of Answers**
Intuitive Interface	1
More Accessible Numbers (Dyscalculia)	1
More Illustrations / Visual Stimuli	2
Use Attractive Colors	1
Less Amount of Text	2
More Direct Instructions	1
Option to Listen Text Being Read Out Loud	1
Contrast Levels Too High/Low	1
Hard to Identify Links	1
Color Palettes That Reduce Eye Strain	1
High-Contrast View Option	1
No "Click Here" Links	1
Use Buttons or Labeled Links	1

The suggestions provided by users encompass various aspects of accessibility and usability, including interface design, text content, visual elements, and navigation features. Some suggestions appear more frequently than others, indicating common areas of concern among users. For example, "More Illustrations / Visual Stimuli" and "Less Amount of Text" are mentioned by multiple users, suggesting a desire for more visually engaging content and concise information.

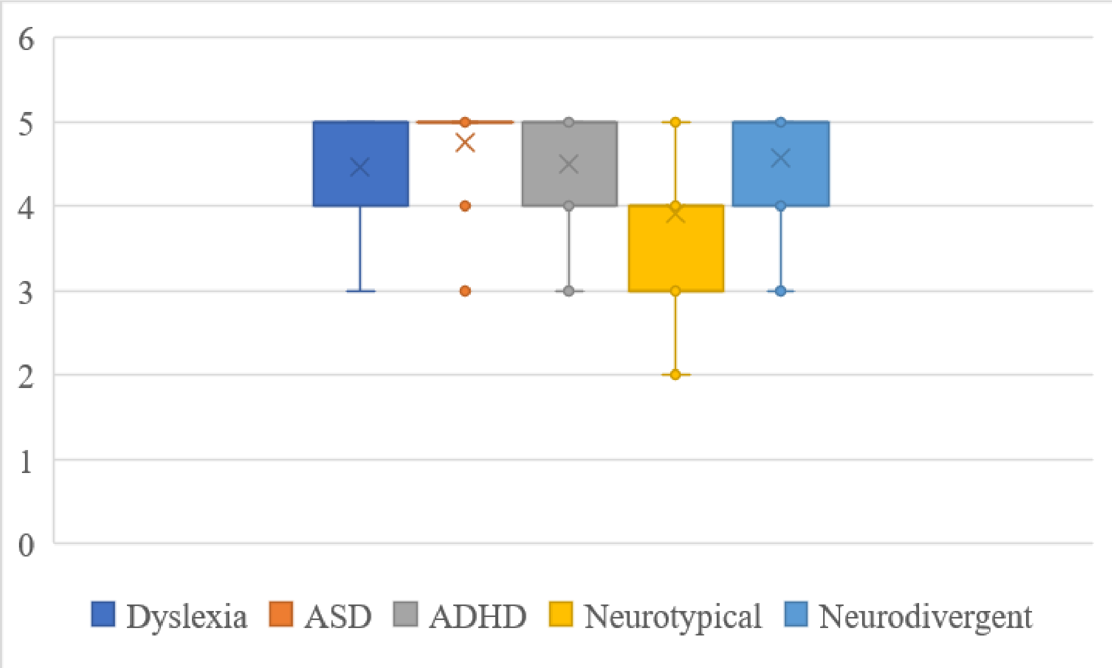


Figure 5.36: Boxplot Graph - Question 3.17

Certain suggestions address specific accessibility needs, such as "More Accessible Numbers (Dyscalculia)", which was written by a user with Dyscalculia, and "Option to Listen Text Being Read Out Loud," highlighting the importance of accommodating diverse user requirements, such as users that have a reading impairment or high difficulty with reading.

Finally, Users emphasize the significance of visual design elements, including color contrast levels, color palettes, and link identification, underscoring the need for user-friendly visual interfaces that prioritize readability and ease of navigation.

Autism Spectrum Disorder

Table 5.4 illustrates suggestions from users with ASD aimed at enhancing usability features on software or websites. Each row within the table represents a distinct suggestion, with the second column denoting the number of user responses supporting each respective suggestion.

Users have proposed a diverse array of suggestions spanning various aspects of usability enhancement, including interface design, navigational aids, accessibility features, and content presentation. Some suggestions appear with greater frequency, indicating common areas of concern or desired improvements among users. For instance, the inclusion of "Clear Instructions" and "More Instructions" highlights a shared desire for improved guidance and clarity within instructions during software or website usage.

Suggestions like "Dark Theme Option" and "High-Contrast View Option" reflect users' preferences for customizable visual settings to improve readability and reduce eye strain.

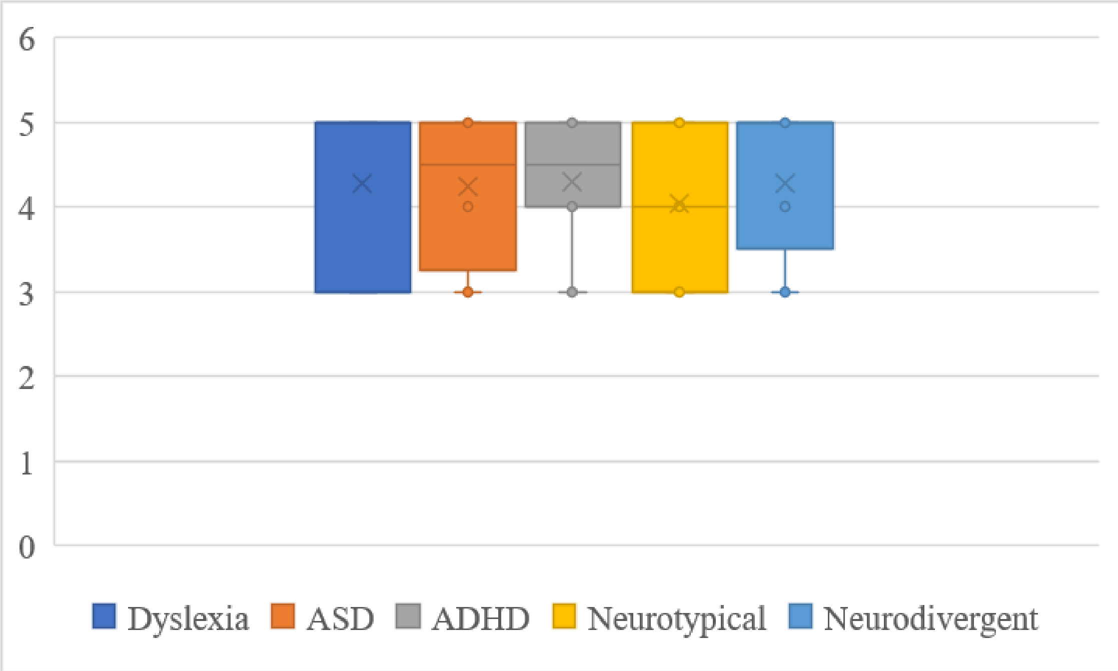


Figure 5.37: Boxplot Graph - Question 3.18

Table 5.4: Answers from Users with Autism Spectrum Disorder

Suggestion	Number of Answers
Window Adjustable Content	1
Fixed Coordinates and Uniform Scaling with Improved Zoom Mechanics	1
Clear Instructions	1
Automatic Mute Settings	1
More Instructions	1
Contrast Levels Too High/Low	1
Hard to Identify Links	1
Color Palettes That Reduce Eye Strain	1
High-Contrast View Option	1
No "Click Here" Links	1
Use Buttons or Labeled Links	1
More Accessible Numbers (Dyscalculia)	1
Dark Theme Option	1
Abolishing Intrusive Ads and Autoplay	1

On the other hand, suggestions such as "Automatic Mute Settings" and "Abolishing Intrusive Ads and Autoplay" emphasize users' desires for a streamlined and less disruptive browsing experience.

Attention Deficit and Hyperactivity Disorder

Table 5.5 presents suggestions from users with ADHD for improving usability features on software/websites. Each row corresponds to a specific suggestion, and the second

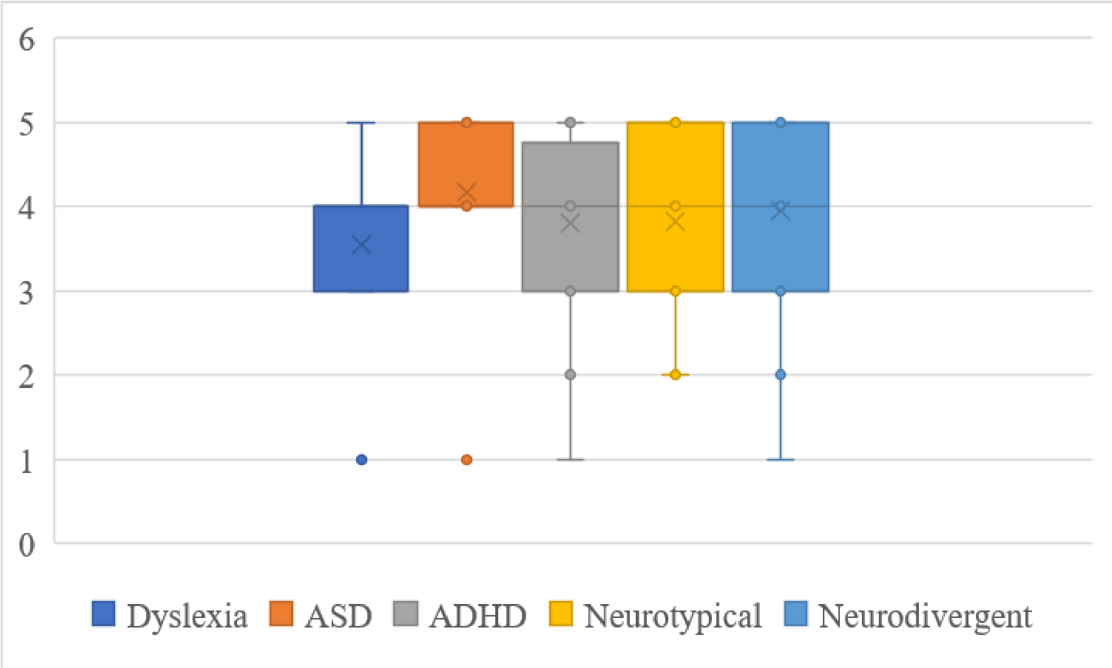


Figure 5.38: Boxplot Graph - Question 3.19

column indicates the number of user responses advocating for that particular suggestion.

Table 5.5: Answers from Users with Attention Deficit and Hyperactivity Disorder

Suggestion	**Number of Answers**
Dark Theme Option	4
Contrast Levels Too High/Low	1
Hard to Identify Links	1
Simple Interface and Navigation	2
Color Palettes That Reduce Eye Strain	1
Less Tabs That Lead to Tabs Extension	1
Guides to Understand the Content	1
Use Buttons or Labeled Links	1
No "Click Here" Links	1
High-Contrast View Option	1
Improve Legibility	1
Abolishing Intrusive Ads and Autoplay	1
Intuitive Interface	1
More Illustrations / Visual Stimuli	1
Use Attractive Colors	1
Less Amount of Text	1
More Direct Instructions	1

The suggestion of implementing a "Dark Theme Option" is notably the most frequently advocated for, with four users expressing a desire for this feature. This indicates a strong preference among users for dark-themed interfaces, which can enhance readability.

Users also emphasize the importance of simplicity and clarity in interface design, as

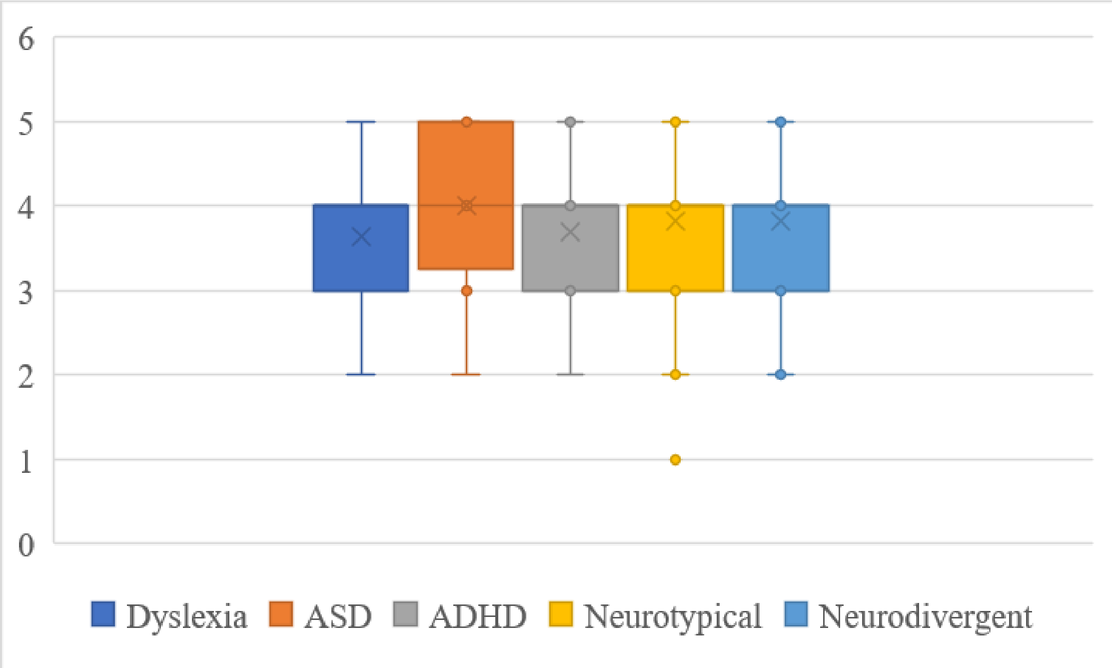


Figure 5.39: Boxplot Graph - Question 3.20

evidenced by suggestions like "Simple Interface and Navigation," "More Direct Instructions," and "Less Amount of Text." These suggestions underscore the need for intuitive and user-friendly designs that minimize confusion and enhance usability.

Other suggestions focus on enhancing the visual appeal and effectiveness of the interface, including "More Illustrations / Visual Stimuli" and "Use Attractive Colors." These suggestions suggest a desire for visually engaging content and color schemes that enhance the overall user experience.

Neurotypical

Table 5.6 illustrates suggestions from Neurotypical users aimed at improving usability features on software or websites. Each row within the table represents a distinct suggestion, with the second column denoting the number of user responses supporting each respective suggestion.

Suggestions such as "Button Size / Manipulation of the Button/Text/etc. Zoom" and "Less Aesthetic Problems / Improve Design, Presentation, and Visualization / Build a Pleasing Interface to the User" underscore the importance of intuitive and visually appealing interfaces that enhance user experience and engagement, while also accommodating certain visual impairment needs.

Users express a desire for streamlined processes with suggestions like "Less Steps to Complete a Task" and "Direct and Clear Information." This suggests a preference for straightforward and efficient workflows that minimize user effort and frustration.

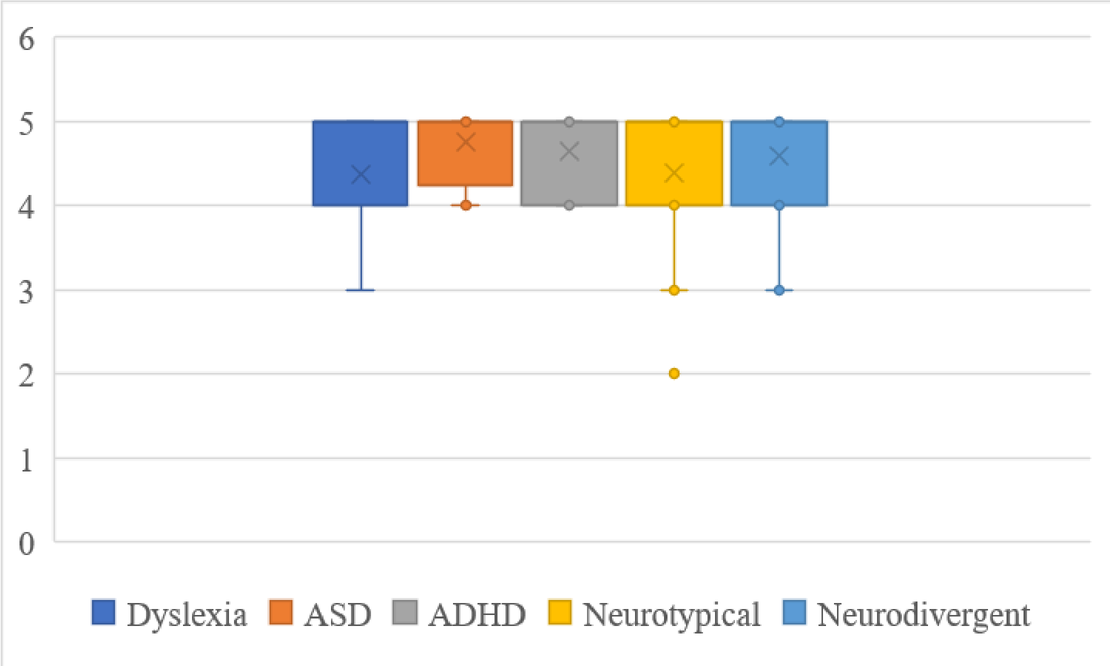


Figure 5.40: Boxplot Graph - Question 3.21

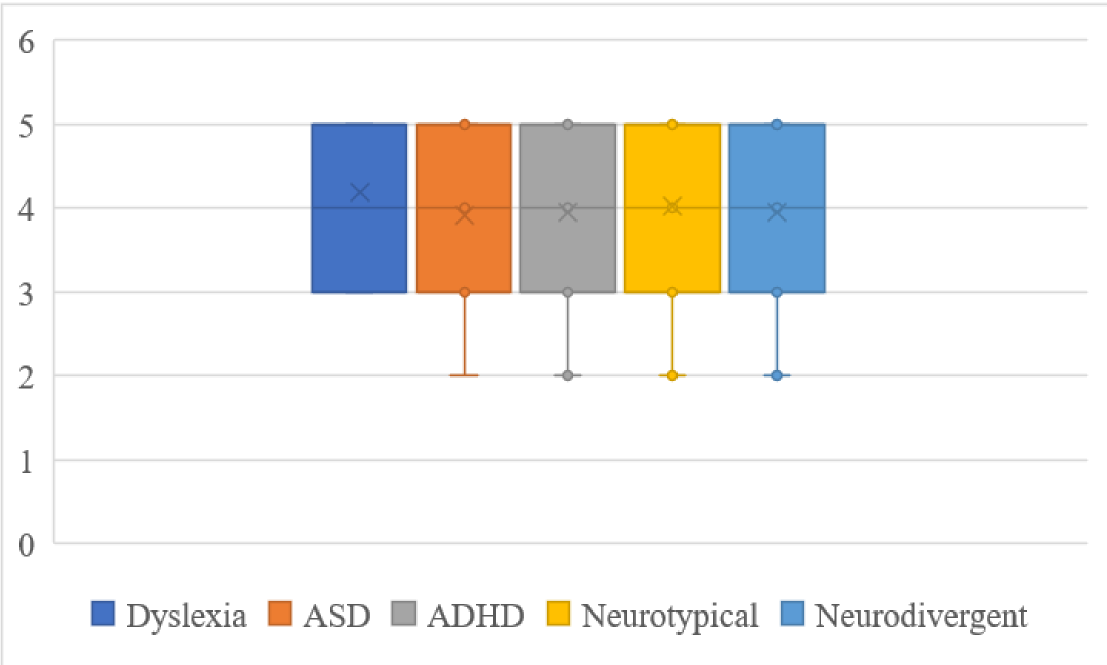


Figure 5.41: Boxplot Graph - Question 3.22

The inclusion of suggestions like "Better Localization of Commands on Page / Commands with More Visibility and Accessibility" and "Poor Writing / Imprecise or Incorrect Language in Instructions" highlights the importance of accessibility and clear communication in ensuring user comprehension.

Finally, suggestions such as "Option to Remember Passwords" and "Dark Mode by

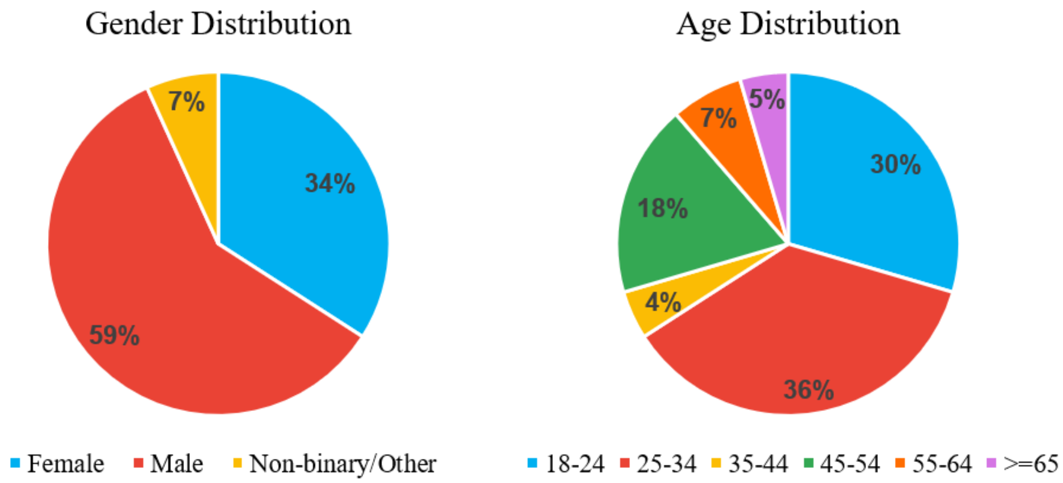


Figure 5.42: Open Ended Questions - Gender and Age

Table 5.6: Answers from Neurotypical Users

Suggestion	Number of Answers
Button Size / Manipulation of the Button/Text/etc. Zoom	2
Less Steps to Complete a Task	1
Better Localization of Commands on Page / Commands with More Visibility and Accessibility	2
Less Aesthetic Problems / Improve Design, Presentation and Visualization / Build a Pleasing Interface to the User	3
Direct and Clear Information	2
Option to Remember Passwords	1
Less Detailed and Confusing Interface	3
Poor Writing / Imprecise or Incorrect Language in Instructions	3
Dark Mode by Default or by Checking an Environment Variable	3
Less Functional Problems	1
Simpler Access	1

Default or by Checking an Environment Variable" reflect users' desire for customization options that cater to their preferences

Neurodivergent

Finally, we decided to include the table 5.7 that presents all the answers and suggestions from users with a Neurodivergent condition. Most of these requirements have been included in the previous sections regarding Dyslexia, ASD or ADHD, but we considered it important to evaluate them in a conglomerate manner.

Suggestions such as "Clear and Simple Interface / Intuitive Navigation" and "Clear

Table 5.7: Answers from Neurodivergent Users

Suggestion	Number of Answers
Poor Readability / Legibility	2
Poor Text Comprehension / Confusing Writing	2
Clear and Simple Interface / Intuitive Navigation	4
Clear Explanations / Direct Instructions / Explain as if Talking to a Child	5
Accessible Numbers (Dyscalculia)	1
More Illustrations / Visual Stimuli	2
Attractive Colors / Color Palettes that Reduce Eye Strain	2
Less Amount of Text	2
Option to Listen Text Being Read Out Loud	1
Window Adjustable Content	1
Fixed Coordinates and Uniform Scaling with Improved Zoom Mechanics	1
Automatic Mute Settings	1
More Instructions	1
Dark Theme Option	4
Contrast Levels Too High/Low (e.g., Black Text on White Background)	1
Hard to Identify the Links	1
Less Tabs That Lead to Tabs Ext	1
Guides to Understand the Content	1
Use Buttons or Labeled Links	1
No "Click *Here*" Where "Here" is the Link	1
High-Contrast View Option	1
Abolishing Intrusive Ads and Autoplay	1

Explanations / Direct Instructions / Explain as if Talking to a Child" received the highest number of responses. This indicates a strong user preference for interfaces and instructions that are easy to understand and navigate. Users value clear explanations and straightforward instructions that help them accomplish tasks efficiently.

Suggestions related to visual design, such as "Attractive Colors / Color Palettes that Reduce Eye Strain" and "Dark Theme Option," indicate that users value aesthetic appeal and customization options. Dark mode, in particular, emerges as a popular feature desired by users with a total of four answers requiring its availability.

5.2 Discussion

We believe the results from section 2 (Software and Website struggles) are following our expectations and believe every relationship was successfully validated. Is worth mentioning the higher-ranked issues among neurodivergent users were issues with concentration, auditory stimuli, and writing for dyslexics.

Although the results from section 3 (Software Requirements) were aligned with our research for the conceptual model, we believe the values obtained from neurotypical respondents for this section did not correspond from their direct experience but a general opinion as they mostly do not struggle with the conditions the solutions were trying to accommodate. For that reason, we believe a comparison between the answers from neurodivergent respondents might not be adequate to our expectations.

Overall, the open-ended results provided valuable insights into user preferences and priorities regarding usability enhancements. However, the limited number of open-ended responses led us to the conclusion that we lacked sufficient information to validate the new requirements mentioned and consequently apply them to our conceptual model.

At the end of the survey, we included two questions that could help us ascertain the general feeling about the survey and the themes it involves. Figure 5.43 shows the respondents' answers to question 4.1 "Do you feel that the software/websites you use adequately accommodate your needs?" with 1 being "not at all" and 5 fully. Although the values are similar, users with ASD have rated the lowest for this question, with an average of 3.3, followed by ADHD with an average of 3.5 and finally Dyslexia with 3.8. The average for neurodivergents was 3.6 and for neurotypicals 3.8. Every group's distribution ranged from 2 to 5 except for dyslexia which had 3 as the lowest answer. Every group has the same variance as well, with 50 % of the answers ranging between 3 and 4. We can conclude that there is a certain need to accommodate websites for neurodivergents, with certain attention to people with ASD and ADHD.

Finally, the last question allowed users to share anything they would like, and those answers are listed in Table 5.8. Respondents acknowledged the innovative nature of the questionnaire and expressed gratitude for the opportunity to contribute. They highlighted the potential for teachers or parents to recognize difficulties in neurodivergent children, indicating the questionnaire's relevance in addressing these issues. One respondent also expressed frustration over platform or program compatibility issues, while others highlighted the need to not forget the individual's ability that can be overshadowed by technology.

Table 5.8: Answers to Question 4.2

Question 4.2. Is there anything else you would like to share with us?
This questionnaire is innovative and some of the answers could be given by teachers or parents who have detected these difficulties in their children! Thank you
My trick for not having to read too much to find the information I need. I copy the text into Google Translate and listen to it being read to me.
It's a shame that when they create a page or programme, they don't do it for all operating systems and we're forced to open different search engines depending on the programme/page we're using.
The Internet is fundamental, but don't forget our individual capacities
Complexity of the task changes instruction requirements

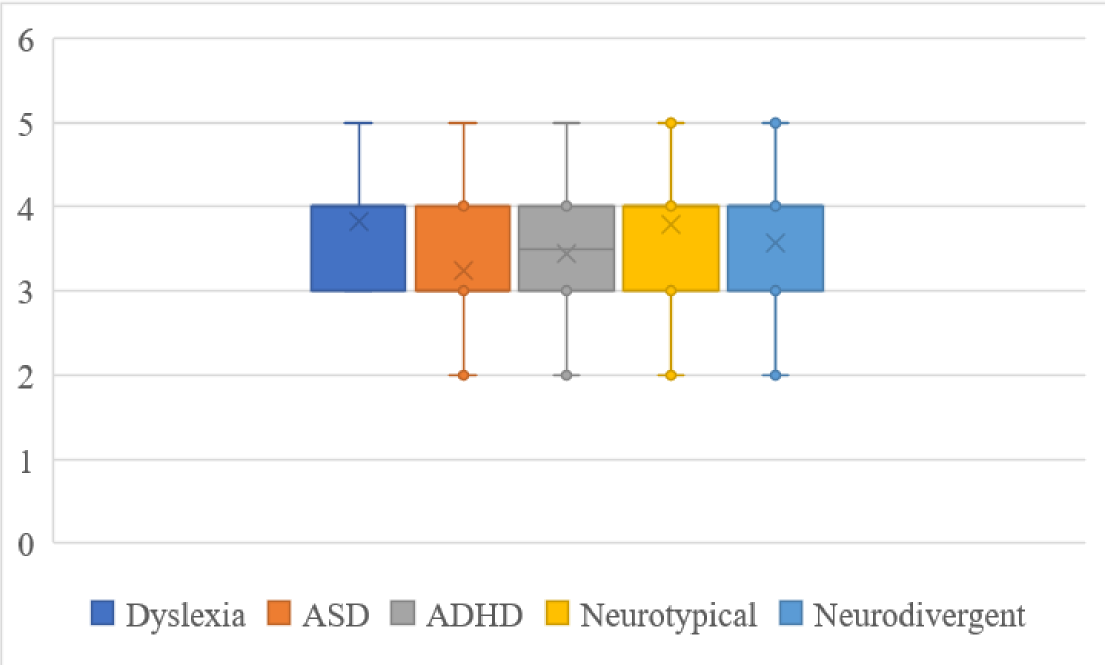


Figure 5.43: Boxplot Graph - Question 4.1

6

A Supporting Tool for Neurogivergent Accessible Requirements

We built a tool to aid the identification of selection of the concepts relevant in a given project. The purpose of this tool is to assist software engineers to understand how accessible to Neurodivergents their software will be and what steps or requirements they could implement.

6.1 A Framework for Neurodivergent Accessible Requirements

The conceptual model we developed in Chapter 4 presents the main concepts and relationships that should be taken into account when making software accessible for neurodivergents. It provides insight about the struggles neurodivergent people face when using software as well as the requirements that can accommodate those struggles. However, to assist better the reading and interpretation of the model, we decided to build a framework based on the conceptual model, that could provide a clear definition of which each concept and include guidelines on how to incorporate it into software to be developed.

6.1.1 NAR Framework

The Neurodivergent Accessible Requirements (NAR) Framework will have the same application domain as the conceptual model. We mapped each set of relationships to a general usability principle and based on the remaining categories we built the general criteria to which the framework will be based on.

Nielsen [29] describes the following 10 general usability principles or heuristics for interface design:

1. Visibility of system status

2. Match between system and the real world

3. User control and freedom

4. Consistency and standards
5. Error prevention
6. Recognition rather than recall
7. Flexibility and efficiency of use
8. Aesthetic and minimalist design
9. Help users recognize, diagnose, and recover from errors
10. Help and documentation

We grouped the concepts and relationships of the model listed on the tables 4.4 and 4.3 into these heuristics and were left with a categorization of our model based on the heuristic it applies to. We discarded heuristics 1, 5 and 9 as our model does not accommodate them.

Finally, we were left with 5 usability principles and general goals on how to address them in a neurodivergent accessible way. The criteria we will present in the following sections is able to evaluate the model in how does it answer the usability principles. We will relate each criteria with the requirements defined to accommodate neurodivergent issues related to the specific principle.

C1: Learnability This criteria applies to all strategies that relate to the software's learnability. This principle emphasizes the importance of providing help and documentation for a system, even though the ideal scenario is to design a system that is intuitive enough to be used without extensive guidance.

Learnability issues:

1. People with ASD, ADHD and Dyslexia struggle with learning issues.
2. People with Dyslexia, ADHD and ASD struggle with task completion.

Guidelines:

1. There must be a clear and simple user guide that eases the learning curve, ideally supported by a video demonstration.
2. Every task should include a simple tutorial that is supported by a video demonstration.

C2: Navigation This criteria applies to all strategies that aim to ease navigation within the software. This principle advocates for reducing the cognitive burden on users by ensuring that relevant objects, actions, and options are readily visible within the interface. Users should not be required to rely on memory to navigate the system or recall information across different parts of the interaction. .

Navigation issues:

1. People with Dyslexia struggle with navigation.

Guidelines:

1. There should be an investigation on how the target users find most logical the organization of content on websites.
2. Interaction elements should be visible and clear.

C3: Simplicity This criteria applies to all strategies aimed to ease simplicity in the system. This principle emphasizes the importance of user-friendly language and intuitive presentation in a system. It suggests using terminology and phrases that users are familiar with, rather than technical jargon.

Simplicity issues:

1. People with Dyslexia struggle with scanning for information.
2. People with Dyslexia, ADHD and ASD struggle with concentration.

Guidelines:

1. The text should contain visual aids as support that makes the content stand out from the rest of the web page.
2. There should be avoided the presence of irrelevant information or distracting media.

C4: Customisability This criteria applies to all strategies aimed to apply costumisability in the system. This principle highlights the need for a clear and easily accessible way for users to exit unintended actions in a system. Furthermore it highlights the need of user control in the system and the freedom of costumizing the page according to their needs.

Customization issues:

1. People with Dyslexia struggle with writing.
2. People with Dyslexia struggle with reading.
3. People with Dyslexia, ADHD and ASD struggle with task completion.
4. People with Dyslexia, ADHD and ASD struggle with concentration.
5. People with ASD struggle with Sensory Issues.

Guidelines:

1. There should be an option to activate a spellchecker function.
2. There should be an option to activate an autocomplete function.
3. There should be an option to activate a reading aid function.

4. There should be an option to activate reminders for the planned tasks.

5. There should be an option to activate scheduling for the planned tasks.

6. There should be an option to activate rewards for the planned tasks.

7. There should be an option to activate a progress tracker for the planned tasks.

8. There should be an option to activate a VR mode.

9. The should be an option to personalise the media displayed and customize it's features.

10. The should be an option to personalise the sound and customize it's features.

C5: Aesthetic and minimalist design This criteria applies to all strategies that apply to minimize the aesthetic and design. This principle highlights that including unnecessary or rarely needed information in a dialogue can detract from the visibility of essential information, as each additional piece of information competes for attention. Therefore, it's crucial to prioritize relevant information to ensure clarity and effectiveness in communication, as well as a pleasing interface and design.

Design issues:

1. People with Dyslexia struggle with reading.

2. People with Dyslexia, ADHD and ASD struggle with task completion.

3. People with Dyslexia, ADHD and ASD struggle with concentration.

4. People with ASD struggle with Sensory Issues.

Guidelines:

1. There should be an increase of font size and avoid low contrast color schemes, also avoid the use of italics or low legible font styling.

2. The User Interfaces should adapt the way the user interacts to the software system to his characteristics, sensory particularities and context of use.

6.2 Supporting Tool for NAR Framework

The tool was built using React with an addition of the reactflow library to aid the model visualisation, and consists of the following main components:

- **NAR Framework Visualisation:** This component with consists in a display of the NAR Framework listed previously fully interactive. The users are guided to a form where they filter the intended usability criteria and visualise the according model as well as a list of the guidelines to include.

- **Conceptual Model Visualisation:** This component provides a visualization of the entire conceptual model developed and includes an option to select from a drop down menu which Neurodivergent condition would you like to include or exclude from the model, origination the corresponding submodel.

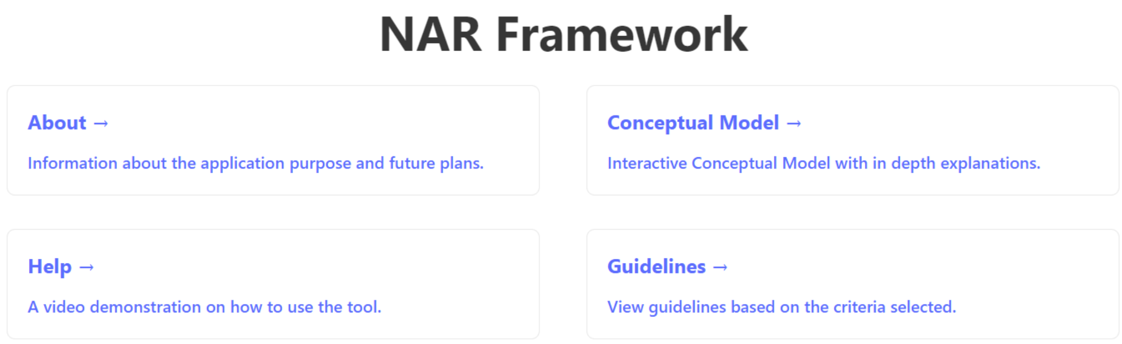


Figure 6.1: Criteria Selection Form

From the homepage 6.1, the users have the following otions: "about", "help", "conceptual model", and "guidelines".

- **About page:** This page includes information about the study and work accomplished as well as the contact information in case they wish to ask any questions or feedback.
- **Help:** This page includes a step by step guide on how the application works with a video support.
- **Conceptual Model:** This is the Conceptual Model Visualisation component. It first redirects the user to a form where they are able to choose from a dropdown list which Neurodivergent condition they wish to apply or filter the model. After the form is submitted they are redirected to the conceptual model page where all the nodes and relationships and clickable and zoomable.
- **Guidelines:** This is the NAR Framework Visualisation component. It first redirects the user to a form where they are able to choose from a dropdown list which usability criteria they wish to apply or filter the model. After the form is submitted they are redirected to the conceptual model page where all the nodes and relationships and clickable and zoomable. The page also includes a list of the usability guidelines they should follow in order to comply with the criteria.

Finally, the application prototype was uploaded into github and can be visualised using the following link NAR Repository.

6.2.1 NAR Framework Visualisation

This is the NAR Framework Visualization component, designed to assist with implementing neurodivergent accessible requirements. Users first select usability criteria from a dropdown menu. After submission, they are redirected to an interactive conceptual model page, featuring clickable and zoomable nodes and relationships, as well as a list of guidelines to follow.

It begins by directing users to a form where they can select usability criteria from a dropdown menu to apply to the model, this page is shown is the following figure 6.2.

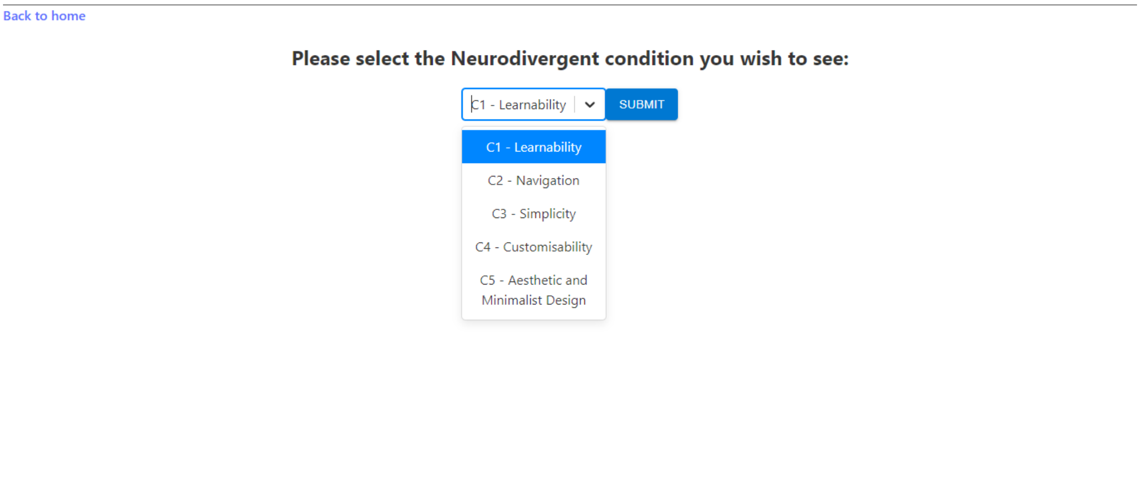


Figure 6.2: Criteria Selection Form

After submitting the form, users are taken to the usability guidelines page, that provides a list of usability guidelines to follow to meet the selected criteria as well as the corresponding submodel with the related nodes and relationships. This page is shown in figure 6.7.

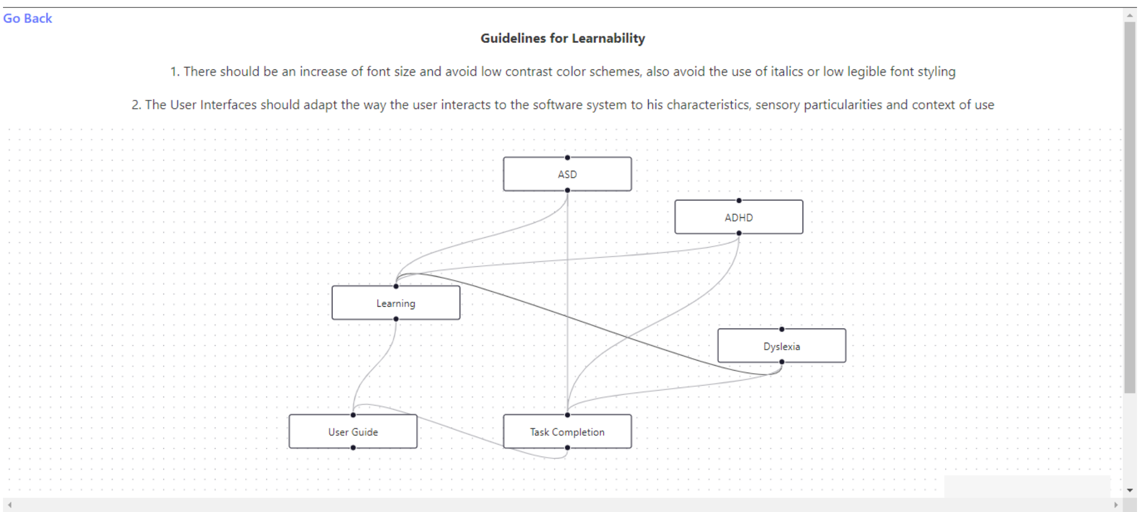


Figure 6.3: Usability Guidelines Page

As a fully interactive model, the users are able to click in the nodes and relationships they wish to investigate, and a modal appears with the definition and attributes when it is applied. An example is shown in figures 6.4 and 6.5.

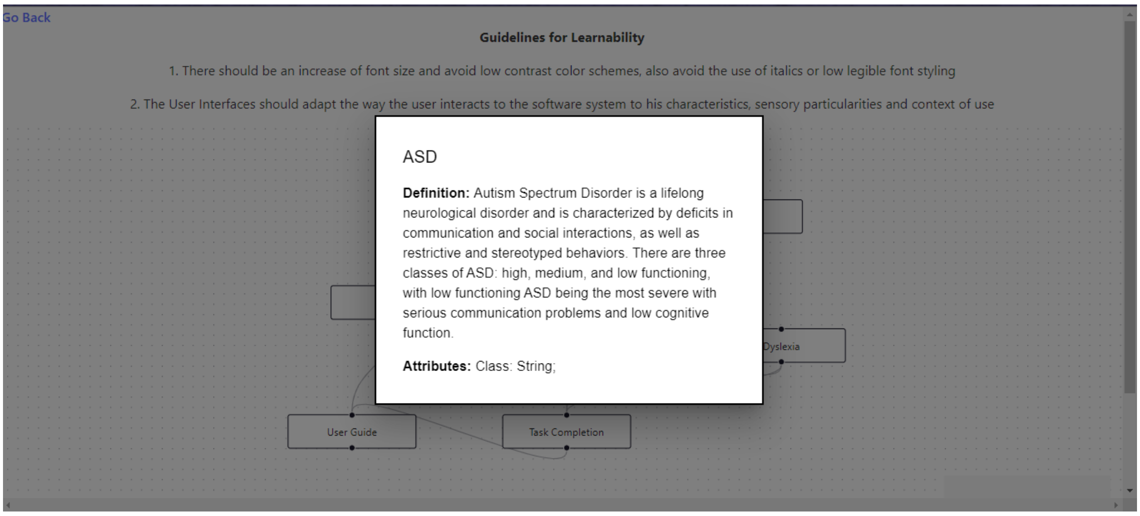


Figure 6.4: Interactive Model - Concept Description

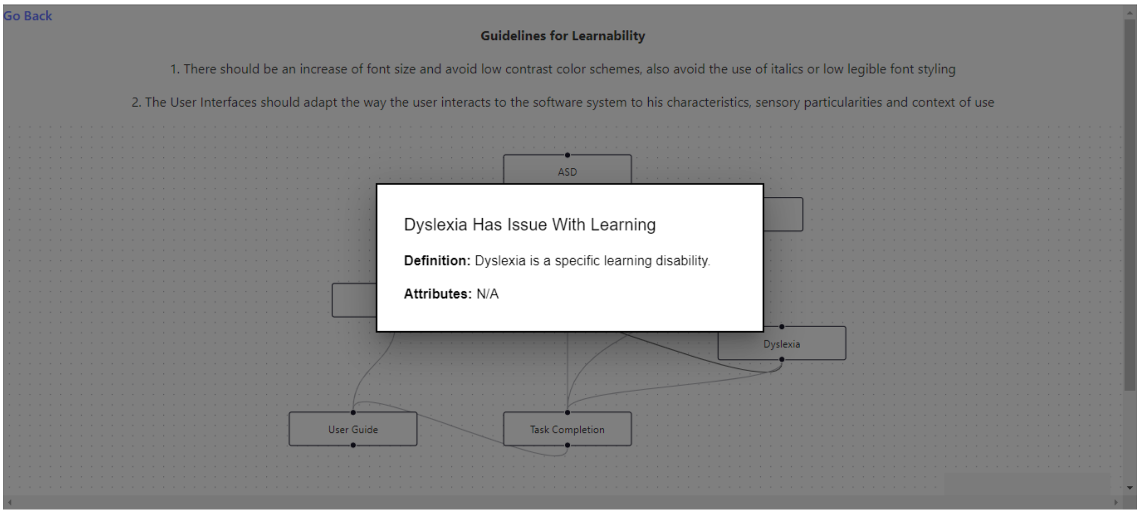


Figure 6.5: Interactive Model - Relationship Description

6.2.2 Conceptual Model Visualisation

The Conceptual Model Visualization component helps users filter the model based on a selected Neurodivergent condition from a dropdown menu. After submitting the form, users are redirected to an interactive page where all nodes and relationships are clickable and zoomable. This component visualizes the entire model and allows users to include or exclude Neurodivergent conditions, generating the corresponding submodel.

It begins by directing users to a form where they can select neurodivergent condition from a dropdown menu to apply to the model, this page is shown is the following figure

6.6.

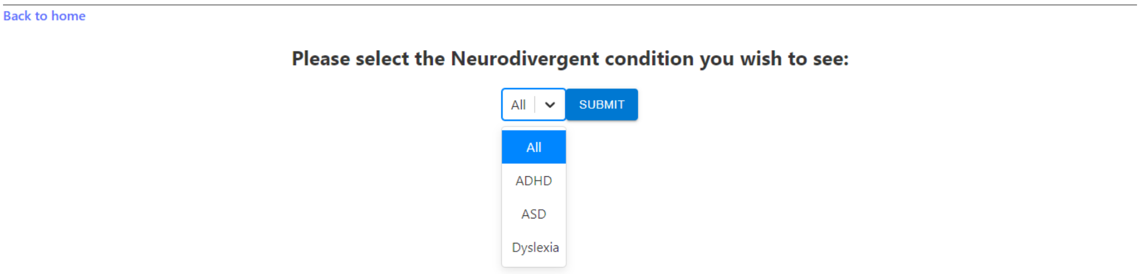


Figure 6.6: Criteria Selection Form

After submitting the form, users are taken to the conceptual model page, that displays the submodel selected. The users are able to click in the nodes and relationships they wish to investigate, and a modal appears with the definition and attributes when it is applied. This page is shown in 6.7.

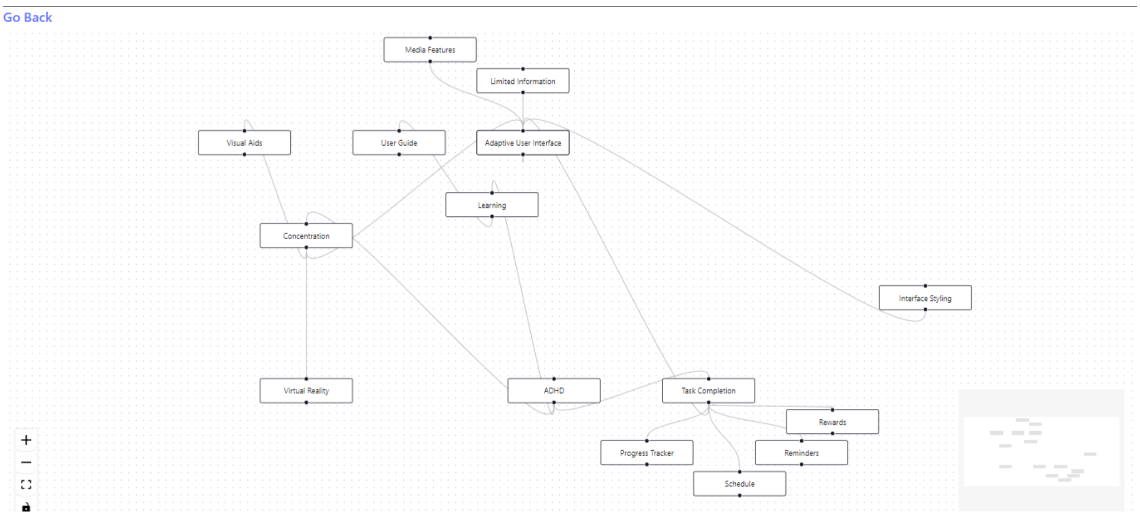


Figure 6.7: Usability Guidelines Page

6.3 Conclusion

We developed a supporting tool that aids the requirements elicitation process by guiding software engineers in the interpretation of the conceptual model developed and by listing accessible guidelines that directly translate into usability requirements.

7

Conclusions and Future Work

This dissertation has embarked on a comprehensive journey toward understanding and addressing neurodivergent issues in software engineering. Through a meticulous process involving a state-of-the-art evaluation, conceptual model development, validation survey, and tool creation, we have made significant strides in elucidating the challenges faced by individuals with Dyslexia, ASD, and ADHD when interacting with software.

The conceptual model crafted from the insights garnered through our SLR (Chapter 4) offers a structured framework that delineates the core issues and their interrelationships. By applying this model to a use case scenario and subjecting it to validation through a survey, we have confirmed its efficacy in capturing the nuanced needs of neurodivergent users.

While the survey analysis provided valuable feedback and affirmed the relevance of our model, it also underscored the importance of considering the perspectives of both neurodivergent and neurotypical users. The disparity in responses between these groups highlights the need for tailored approaches that account for the unique experiences and challenges faced by neurodivergent individuals.

We surpassed our expectations with a total of 100 contributions to the survey responses and we consider to have achieved a well diverse group so that the answers are valid and can be taken into consideration for other studies and literature reviews.

Furthermore, the tool developed in this dissertation represents a practical contribution to the field, offering guidance to software engineers in interpreting the conceptual model and facilitating the requirements elicitation process. By integrating accessibility considerations into the software development lifecycle, we aim to foster greater inclusivity and usability for neurodivergent users.

In essence, this dissertation not only sheds light on the barriers encountered by neurodivergent individuals in software engineering but also provides a framework and tools to address these challenges effectively.

7.1 Future work

Moving forward, we aim to carry out a new survey with some of the additional input we obtained with our survey and hopefully be able to reach a wider population of neurodivergent individuals, with perhaps the contribution of an institution.

In addition, we believe the NAR Framework can be embedded into current workflows, promoting a more user-centric approach that ensures the development of software products that are both functional and inclusive. Its focus on accessibility not only addresses the needs of neurodivergent individuals but also enhances inclusivity in software development processes with its real-world applicability and ease of use.

Furthermore, we believe the supporting tool has great potential to be integrated into an already existing tool used by software engineers. I started my professional career two years ago and since then I have been included in numerous of different projects. The main tool used in requirements planning and task distribution is Jira, and we believe it would be an interesting and useful addition to integrate the supporting tool develop with Jira so it could apply the appropriate requirements into Jira tasks and dependencies.

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A

Class Diagram

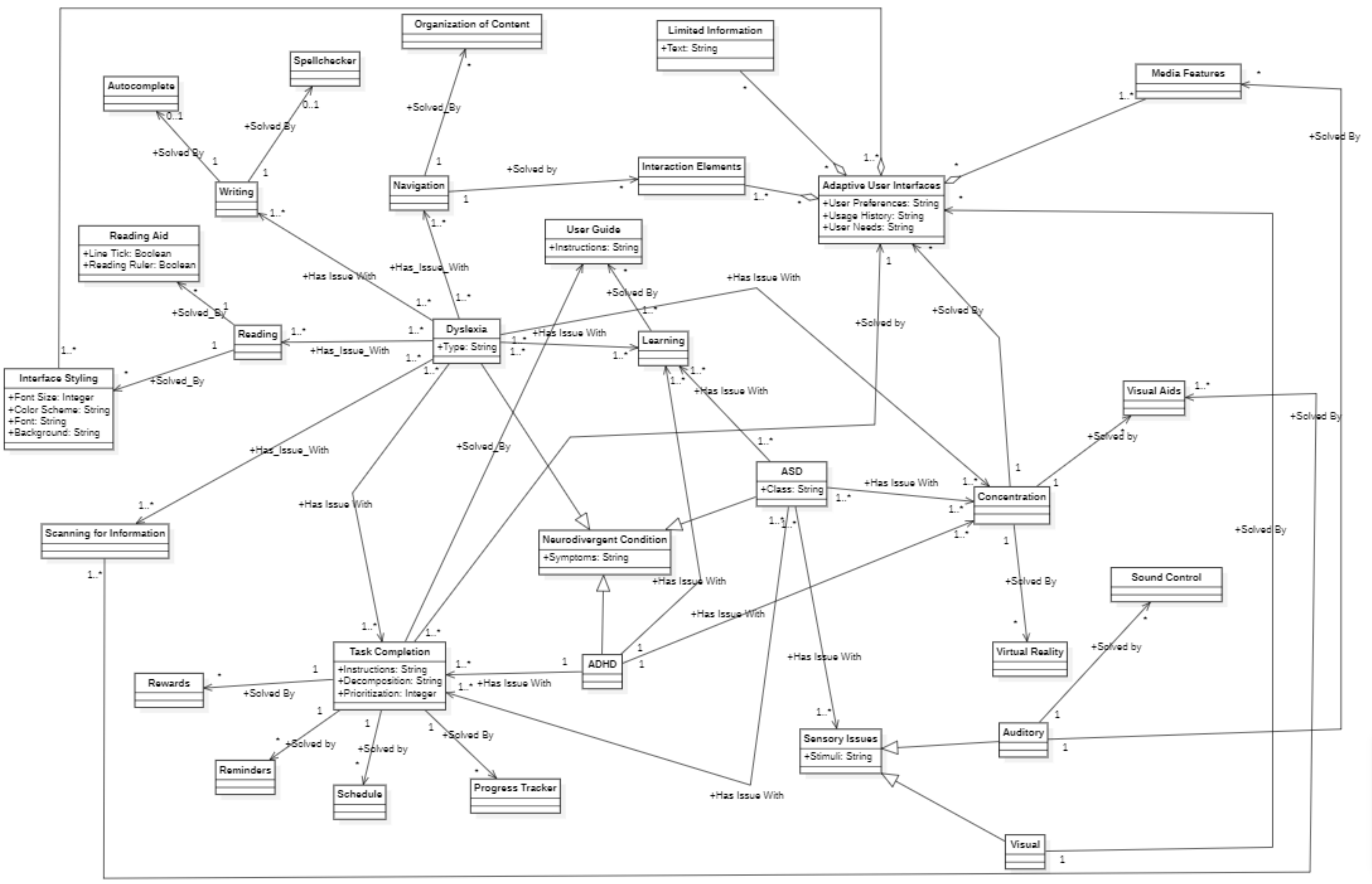

Figure A.1: Class Diagram

B

Sub Diagrams

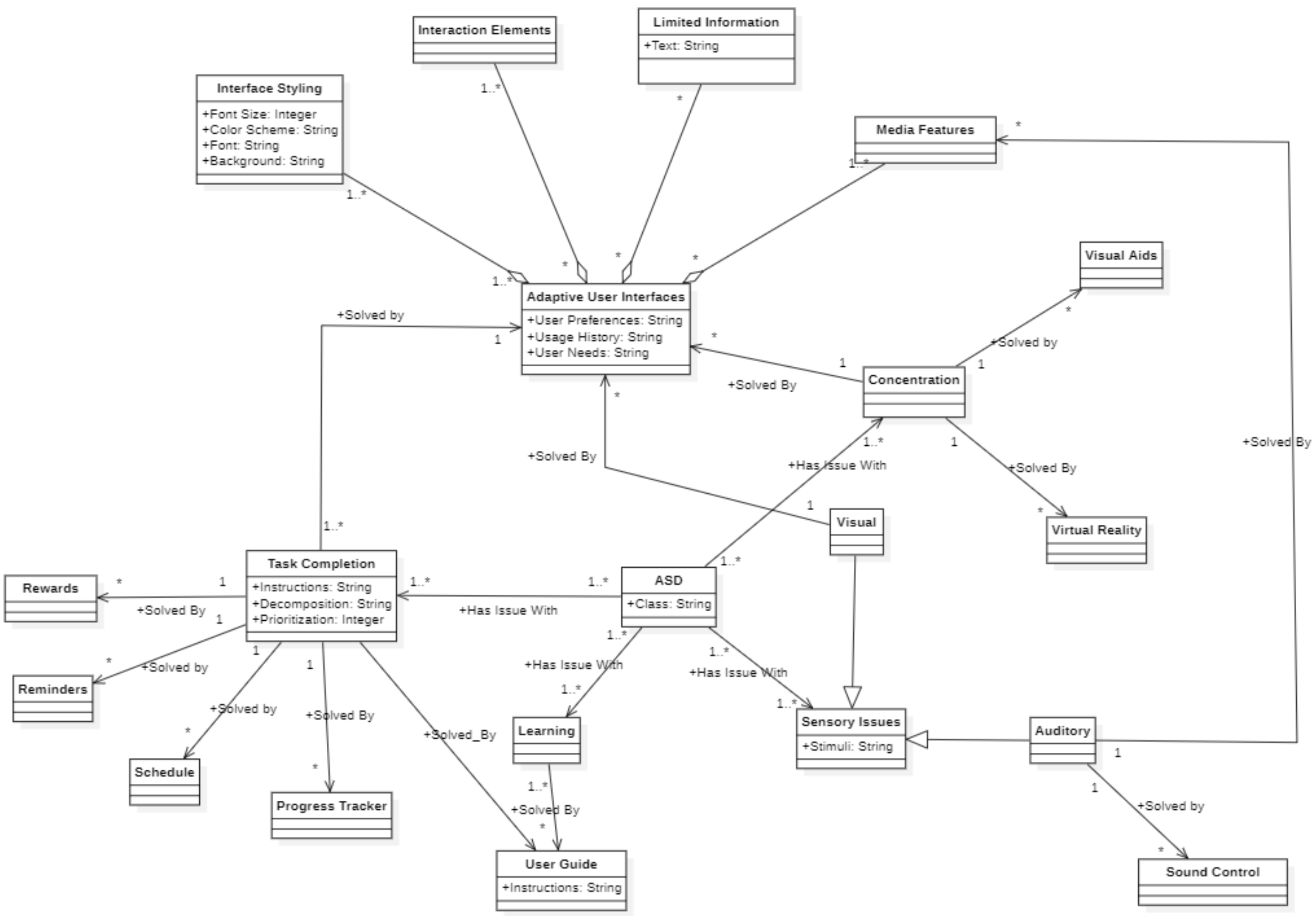

Figure B.1: ASD Sub Diagram

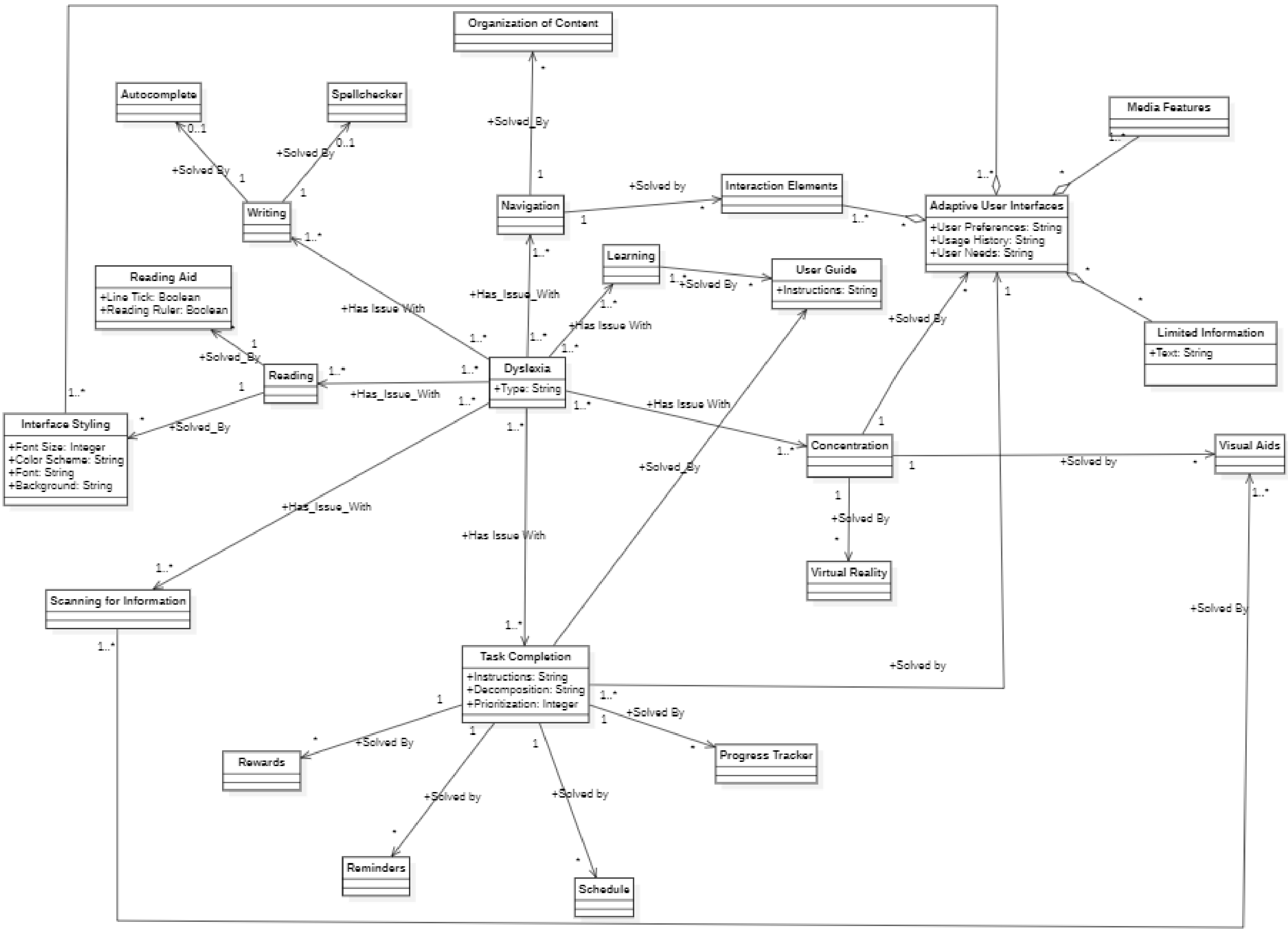

Figure B.2: Dyslexia Sub Diagram

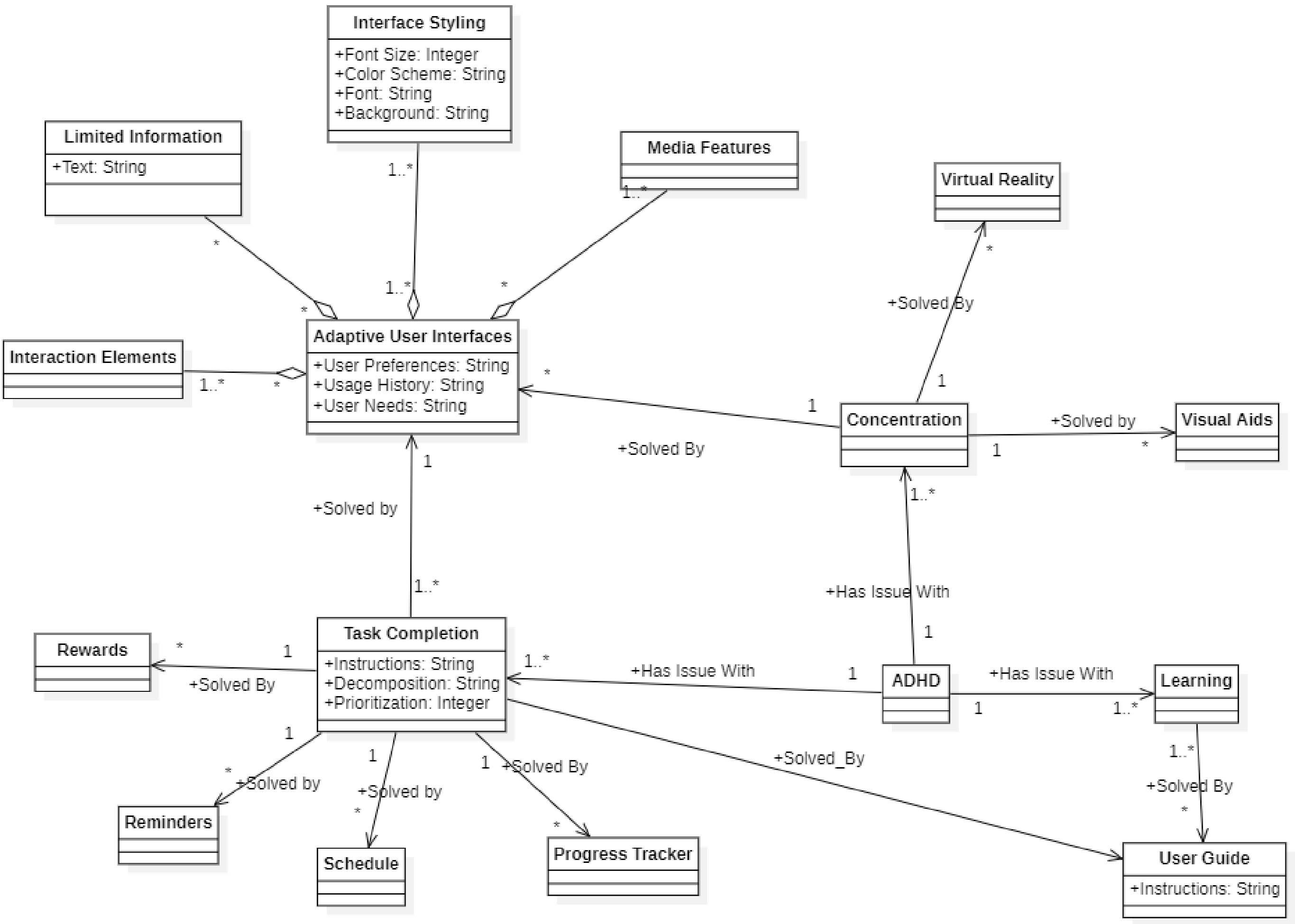

Figure B.3: ADHD Sub Diagram

C

Validation Survey

Neurodivergent Struggles in Software Engineering

Dear Participant,

I invite you to participate in this survey aimed at investigating the struggles neurodivergent people face while using software/websites and which techniques are effective to solve them. Currently, I am pursuing my Master's degree in Computer Science in Nova's School of Science and Tecnology, and this survey forms an important part of the research for my Master's dissertation.

Your participation in this research is entirely voluntary, and you have the freedom to withdraw at any point during the survey. Your responses will remain confidential and anonymous and will only be used within the context of this study. No one will know your individual answers to this
questionnaire.
The survey consists of four pages and includes both multiple-choice questions and optional open-ended questions. If you choose to participate, I kindly ask that you answer the questions to the best of your ability. It should take approximately 10 minutes to complete the questionnaire.

The data collected from this survey will be utilized for research purposes, specifically to enhance our understanding of software accessibility and to develop comprehensive requirements aimed at ensuring accessibility for all users. Your valuable input will greatly contribute to our efforts in addressing this important issue.
If you have any questions or concerns about this project, please do not hesitate to reach out to me at il.rocha@campus.fct.unl.pt.

Thank you in advance for considering participating in this study.
Sincerely Yours,
Inês Rocha

* Indicates required question

1. 1.1. Please specify your gender: *

2. 1.2. Please select your age: *

Mark only one oval.

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- >=65

3. 1.3 Do you have any Neurodivergent Conditions (e.g., bipolar, obsessive compulsive, dyslexia, autism spectrum , attention deficit hyperactivity)? *

Mark only one oval.

- Yes *Skip to question 4*
- No *Skip to question 7*

4. 1.4. Please select which Neurodivergent conditions do you have from the following: (you can select more than one answer) *

Check all that apply.

- Autism Spectrum Disorder (ASD)
- Dyslexia
- Attention Deficit Hyperactivity Disorder (ADHD)
- Bipolar Disorder
- Obsessive Compulsive Disorder
- Other: ______________________

5. 1.5. Do you have an official diagnosis for any of those conditions? *

Mark only one oval.

- Yes
- No

6. If your previous answer was yes, please list which diagnoses do you have:

Software and Website struggles

This section deals with the struggles encountered when using different software interfaces and websites. For every concept defined in the conceptual model as an issue we mapped it into a question that validates its frequency.

Please indicate the degree of frequency with the following questions on a scale of 1 to 5 with the extremes: 1= Never, 5= Always.

7. 2.1. When using a software/website, how frequently do you struggle with poor readability? *

Mark only one oval.

	1	2	3	4	5	
Nev						Always

8. 2.2. When using a software/website, how frequently do you struggle with comprehending what is written? *

Mark only one oval.

	1	2	3	4	5	
Nev	◯	◯	◯	◯	◯	Always

9. 2.3. When using a software/website, how frequently do you struggle with performing tasks? (e.g. register on page) *

Mark only one oval.

	1	2	3	4	5	
Nev	◯	◯	◯	◯	◯	Always

10. 2.4. When using a software/website, how frequently do you struggle with visual stimuli (e.g., flashing images)? *

Mark only one oval.

	1	2	3	4	5	
Nev	◯	◯	◯	◯	◯	Always

11. 2.5. When using a software/website, how frequently do you struggle with auditory stimuli (e.g., loud sounds)? *

Mark only one oval.

	1	2	3	4	5	
Nev	◯	◯	◯	◯	◯	Always

12. 2.6. When using a software/website, how frequently do you struggle with concentration? *

Mark only one oval.

	1	2	3	4	5	
Nev	◯	◯	◯	◯	◯	Always

13. 2.7. When using a software/website, how frequently do you struggle with writing (e.g., spelling, grammar)? *

Mark only one oval.

	1	2	3	4	5	
Nev	◯	◯	◯	◯	◯	Always

14. 2.8. When using a software/website, how frequently do you struggle with learning how to use it? *

Mark only one oval.

	1	2	3	4	5	
Nev	◯	◯	◯	◯	◯	Always

15. 2.9. When using a software/website, how frequently do you struggle with finding the information you need? *

Mark only one oval.

	1	2	3	4	5	
Nev	◯	◯	◯	◯	◯	Always

16. 2.10. When using a software/website, how frequently do you struggle with following instructions? *

Mark only one oval.

	1	2	3	4	5	
Nev	◯	◯	◯	◯	◯	Always

17. 2.11. Besides the struggles mentioned above, do you have any more concerns when using a software/website regarding accessibility?

18. 2.12. How do you think those concerns should be addressed?

Software Requirements

This section evaluates specific software requirements that deal with the struggles discussed in the previous section. For every concept defined in the conceptual model as a solution we mapped it into a question that validates its effectiveness.

Please indicate the degree of agreement with the following statements on a scale of 1 to 5 with the extremes: 1= Strongly Disagree, 5= Strongly Agree.

19. 3.1 A colored background and contrasting bold letters are easier to read. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

20. 3.2. A reward at the end of the task is effective in helping with task completion. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

21. 3.3. Alarm reminders are effective in helping with task completion. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

22. 3.4. An organized schedule is effective in helping with task prioritization. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

23. 3.5. A task progress tracker is effective in helping with task completion. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

24. 3.6. An automatic spellchecker is effective in helping with writing. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

25. 3.7. Smart autocomplete is effective is helping with writing. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

26. 3.8. Avoiding redundant instructions help with following instructions. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

27. 3.9. Clear and concise writing helps with following instructions. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

28. 3.10. More detailed information helps with following instructions. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

29. 3.11. Visual aids (e.g., illustrations) help with finding the information you need. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

30. 3.12. Limiting the amount of text is effective in helping with concentration. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

31. 3.13. Virtual Reality software/websites is effective in helping with concentration. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

32. 3.14. Reading aids (e.g., a word tracer like in karaoke) are effective in helping with reading. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

33. 3.15. Customizing the information displayed (e.g., using a filter) is effective in helping with concentration. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

34. 3.16. Visual illustrations are effective in helping with concentration. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

35. 3.17. Sound customization (e.g., volume control) are effective in helping with auditory overstimulation. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

36. 3.18. Visual customization (e.g., brightness control) are effective in helping with visual overstimulation. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

37. 3.19. A descriptive user guide helps with software/website learning. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

38. 3.20. More detailed instructions help with software/website learning. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

39. 3.21. Clear organization of elements helps with page navigation. *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

40. 3.22. Customizing the position of page elements (e.g., favorites tab) helps with page navigation when using a software/website? *

Mark only one oval.

	1	2	3	4	5	
Strc	◯	◯	◯	◯	◯	Strongly Agree

Software Accessibility

This is the final section and it contains some general questions about the importance of software accessibility.

41. 4.1. Do you feel that the software/websites you use adequately accommodate your needs? *

Mark only one oval.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Fully

42. 4.2. Is there anything else you would like to share with us?

This is the end of the survey. Thank you so much for your help!

D

Supporting Tool

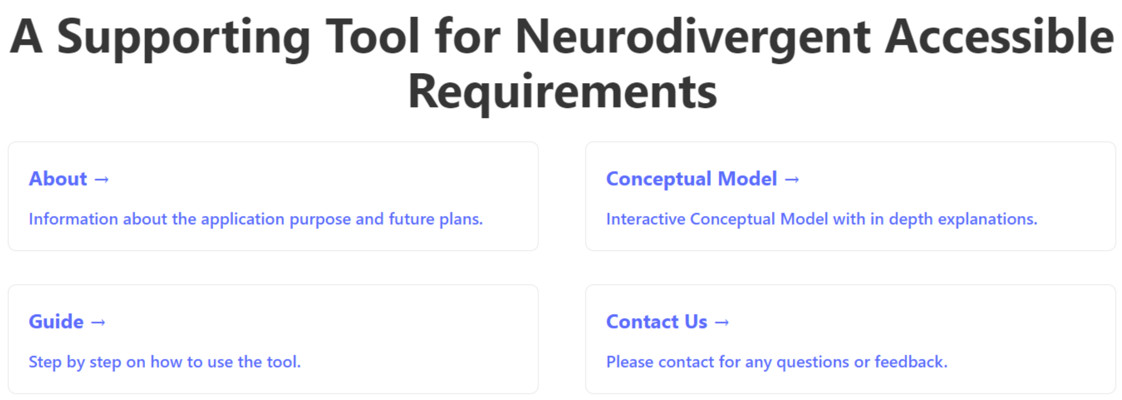

Figure D.1: Homepage

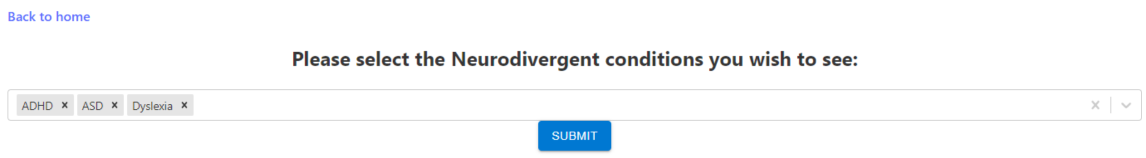

Figure D.2: Selector

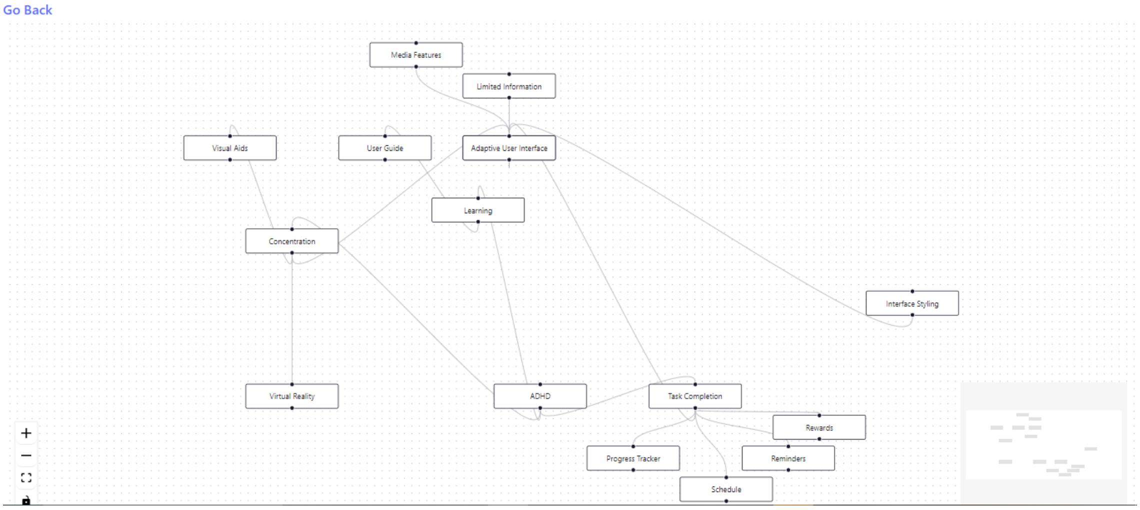

Figure D.3: Filter Applied - ADHD

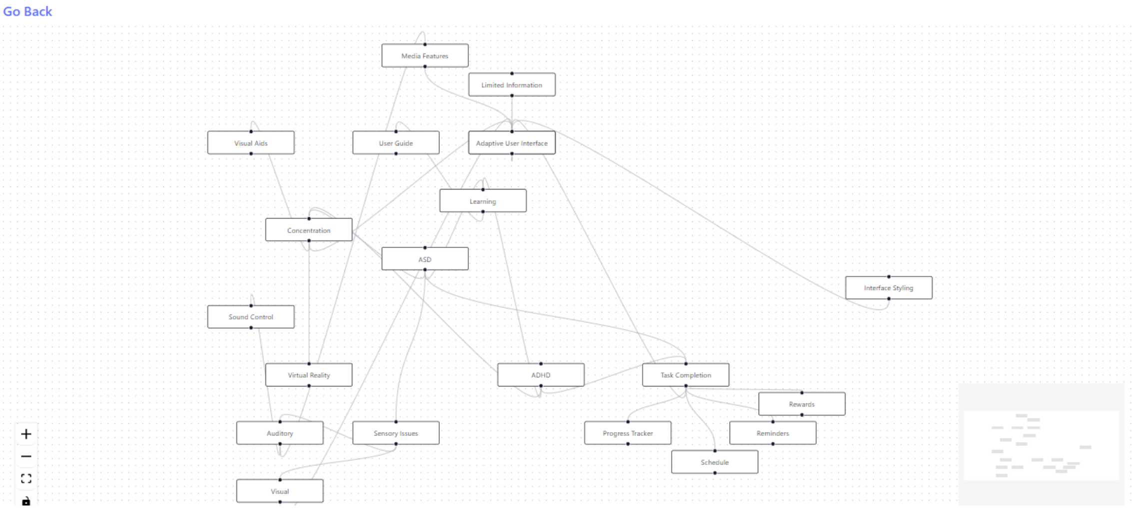

Figure D.4: Filter Applied - ADHD and ASD

2024 A Conceptual Model on Neurodivergent Issues in Software Engineering Inês Rocha

NOVA
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