

# Developing Usability Heuristics for Bangladeshi E-Commerce Websites: A Desktop and Mobile Focused Approach

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A thesis submitted to the Department of Computer Science and Engineering  
in partial fulfillment of the requirements for the degree of  
B.Sc. in Computer Science

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# Declaration

It is hereby declared that

1. The thesis submitted is my/our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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# Approval

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# Abstract

In the era of digital technology, the importance of E-commerce has been immense, impacting economies, consumers and businesses alike. In Bangladesh, the use of E-commerce has completely changed the business landscape over the past decade as a result of greater internet access, advancements of financial technology and peoples' purchase behaviour. It is necessary to ensure E-Commerce websites, being made everyday, are tested on all fronts with one of the major criterias being user experience. Despite major improvements in all forms of testing, usability testing has received very little attention. Usability testing is used to validate the user experience of a website and often evaluating with real-time users is expensive so alternative methods such as heuristic evaluation are on the rise. Nielsen's heuristics are the most commonly used tool for heuristic evaluation. Developed back in 1994, these rules are generalized and no longer suitable for evaluating modern websites and their experiences in different types of devices. Therefore they also give incorrect results when used on Bangladeshi E-commerce websites. This paper focuses on developing heuristics for E-Commerce websites that users can use both on their personal computers and mobile devices. This paper uses a modified version of Rusu's methodology to develop new heuristics. A comparative study is then conducted between Nielsen's heuristics and our proposed new set of heuristics for E-commerce websites using the Method Adoption Model. This evaluation was done by professionals currently working in the industry to reach a valid conclusion.

**Keywords:** Usability Testing; Heuristic Evaluation; Usability Heuristics; E-Commerce;

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# Chapter 1

## Introduction

Usability, as defined by ISO/IEC25010 and ISO 9241-11 refers to ‘the degree to which a product or system allows specific users to achieve their goals with efficiency, effectiveness and satisfaction in a particular context of use’[10] [48]. Heuristic evaluation is an informal usability analysis method where a group of evaluators assesses a user interface by reviewing against a predefined set of guidelines.[1]. These rules vary between products, however, a certain set of rules were established for certain products such as websites. Heuristic evaluation helps to find usability issues in a user interface early in the design process. It involves a small group of evaluators who assess the interface and evaluate it based on usability principles. It was found that heuristic evaluation is extremely cost efficient, proving that it is valuable in circumstances where time and funding are limited. As only a small group of evaluators conduct heuristic evaluation, end users are not required to participate during the evaluation[2]. However, as companies integrate new features into their websites to improve the functionality of their website which makes it difficult to assess such features based on current usability heuristics using Nielsen’s heuristics[25] Ever since the pandemic, there has been massive rise in the usage of online services since social distancing has been enforced. The statement is true for E-commerce specially in the context of Bangladesh which saw the creation of more E-commerce websites. The creation of all these websites also required an increasing focus on the user-centric design of e-commerce platforms, which specifically aimed to enhance the overall user experience. According to Nielsen, conversion rates are a Key Performance Indicator in an e-commerce website to understand its impact and performance. Conversion rate is the amount of users who perform a desired action in the website, such as adding an item to the cart, proceeding to checkout, etc. Good usability directly portrays how a regular visitor can become a paying customer. Increased customer conversion is a strong ROI factor of improved usability and user experience.[5]. With the rise of online commerce, there is a need for usability heuristics that are specifically designed for e-commerce websites. This paper will focus on developing heuristics for e-commerce sites in Bangladesh, with an emphasis on measurable values.

### 1.1 Research Problems

Currently, people use Nielsen’s heuristics for evaluating user interfaces. However, Nielsen’s heuristics were created over 3 decades ago during the early days of the

internet. Within these 30 years, the number of websites have grown significantly with the rise of newer domains and much smaller devices as well as the adoption of JavaScript for enriching user experience among websites. With the addition of newer features to improve the functionality of a website, it becomes difficult to evaluate a user interface specially using Nielsen’s heuristics [25]. As a result, it becomes important to either modify the set of heuristics so that they are more appropriate for newer web applications [33]. Moreover, these heuristics might provide incorrect information for these applications in the form of false positives and false negatives [29]. They might judge certain aspects of the website to be poor even if they are actually useful or consider them good even if they are harmful. The incorrect scores assigned by the current set of scores might cause companies to move on to other alternatives of usability testing away from heuristic evaluation. As a result, it is necessary to create a new set of heuristics for usability testing that would be specific to the domains of each website that would be able to provide more reliable results and be more consistent across similar platforms. Furthermore, these heuristics use comments from experts and do not have any specific quantifiable value. As a result, it becomes difficult to determine which rules would hold more value when evaluating a website or determine the importance of a comment for the website which would undermine its usefulness as well [22]. Over this time, E-commerce websites have also evolved by incorporating more advanced technologies multiple forms of transaction processing both online and offline, tracking of order through gps, more responsive design and so on. So, it would be necessary to create specific heuristics for specific features of E-commerce websites for their usage in both desktop and mobile devices which would try to fill the gap left by general usability heuristics such as that of Nielsen’s. This paper focuses on the development of a concise set of heuristics for usability testing that can be utilized for testing E-commerce websites using a quantifiable value so that companies can easily make a more informed decision for the improved usability of their websites.

## 1.2 Research Objectives

This research aims to develop a new set of usability heuristics in comparison to already existing usability heuristics by focusing primarily on Bangladeshi e-commerce websites. We plan to create a new heuristic by extending on Nielsen’s current heuristics along with other notable heuristics. Furthermore, we hope to add extra heuristics for mobile applications or modify the currently provided heuristic to better account for different types of devices. Additionally, we would survey other studies on the usability of e-commerce websites as well as similar e-commerce specific usability heuristics if they exist to develop new heuristics that would better conform to modern day Bangladeshi e-commerce websites. Moreover, simply creating a set of heuristics would not be enough it would also be necessary to evaluate them to reach a conclusion of whether they would be appropriate for use in the industry as well as comparing it with that of Nielsen’s. In order to ensure that the heuristics are industry ready, we have decided to use evaluators who have been working in the industry to ensure that we reach an industry ready set of heuristics specific for e-commerce websites. In short, the objective of this research can be summarized as:

1. Design a new set of usability heuristics that would better suit E-commerce websites
2. Ensure that it can be readily used by those already working in the industry
3. Compare the created heuristic with that of Nielsen's
4. Ensure the usability heuristics can be quantified so that more informed decisions can be made

## 1.3 Thesis Structure

- In Chapter 2, the thesis focuses on literature review and background first elaborating on previous work that has been done regarding the development of new heuristics. Since, there are almost no papers that focus on development of heuristics on multiple domains, most of the papers focus on development of single domain heuristics. The background consists of all the required knowledge that will be needed to grasp a better understanding of the paper which would be later used throughout the thesis.
- Chapter 3 consists of the methodology. Since, no method has been developed for multiple heuristics, an existing method has been modified so that heuristics can be developed for E-commerce websites on both mobile devices and personal computers we have developed one through a combination of previous methods with small improvements
- In chapter 4, the data analysis and results section, this methodology was followed to perform data analysis and the newly created heuristic was compared with another set of heuristic to achieve an effective result. This comparison was done based on the number of problems found, relation to user testing as well as the usage of an already existing model to evaluate each heuristic.
- In chapter 5, a section is dedicated to the conclusion consisting of our closing remarks as well as the focus on the limitations that this research has and what can be done in the future to improve upon this work.

# Chapter 2

## Literature Review and Background

### 2.1 Literature Review

In this paper [36], the authors have proposed a new heuristic by combining Nielsen's Ten General Principles for Interaction Design and Tognazzini's First Principles of Interaction Design. In order to do so, they have revised both the lists to understand the focus of each principle in each list. Secondly they compared the principles from one list to the other to find common duplicates that they then merged together. Finally they created the list by creating a new set of rules and replacing the duplicates with a single rule as well as replacing rules with a lot of similarity as a single rule containing the principles from each list which resulted in a total of 15 rules. Next, they went on to add more in-depth and specific rules for each principle so that they would be easier to refer to as well as be used by others. Each of these in-depth principles were given a score of values 0, 0.5 and 1 with the addition of a non-applicable score. The score for a website was obtained by adding all the scores by an evaluator and then dividing it by the total score without the non-applicable scores which would provide a percentage score they named Usability Percentage. Finally they evaluated the website provided by their university with seven evaluators who performed the heuristic evaluation and provided comments and a comparison of the newly developed heuristics with other heuristic methods.

In this paper [29], the author has given a comparative analysis between his created usability heuristics and Nielsen's heuristics. This heuristic consists of all of Nielsen's rules summarized to 9 with the addition of six more heuristics including a resemblance between the system's interface design and the user's cultural aspects, a feedback mechanism that helps users to rollback from errors, adherence to web design principles, design consistency among pages, the guarantee that operations will be completed in the allocated time under all conditions and the offering of correct functionality and implementation of all elements in the system. The Method Adoption Model or MAM was used to evaluate the system with focus on perception-based variables consisting of perceived ease of use, intention to use and perceived usefulness. 46 undergraduate students were taken for the experiment divided into two groups of 21 and 25 students with each group to perform heuristic evaluation on a website named Booking.com. The 21 students were to perform heuristic eval-

uation with Nielsen’s rules while the group of 25 would do it with the author’s created heuristics. After the testing, the users from each group would be asked their opinions on the perceived usefulness, the perceived ease of use and intention to use through a point based system ranging from 1 to 5 in order to perform a comparison where the usefulness of both the systems was close but the perceived ease of use was much better in the newly created heuristic.

In this paper [27], the authors developed a new set of 12 usability heuristics that are tailored specifically for smartphones. By reviewing existing heuristics like Nielsen’s Ten Usability Principles, they identified limitations in applying these to mobile devices. They created an initial set of heuristics for touchscreen devices, which was refined into ‘SMASH’ through iterative testing and validation. ‘SMASH’ was tested against Nielsen’s heuristics through experiments involving various smartphones. These tests showed that ‘SMASH’ identified more severe usability issues, particularly mobile-specific ones like touch gestures and screen size limitations unlike Nielsen’s Ten Usability Principles. The final set was validated through a heuristic evaluation of the Dropbox mobile app, showing that ‘SMASH’ provides better coverage of smartphone specific usability problems. The authors concluded that domain specific heuristics like ‘SMASH’ are essential for accurately assessing usability in specialized contexts. Non domain specific heuristics may overlook critical issues.

In this paper[23], the authors developed a new set of heuristics specifically for Learning Management Systems (LMS) in African institutions. Their work was driven by the need to address the usability challenges faced by institutions in Africa, where low usage of LMS was prevalent, partly due to a lack of usability evaluations. To develop these heuristics, they adapted and refined Nielsen’s Ten Usability Heuristics to fit the unique contexts of LMS, taking into account both interface usability and didactic effectiveness. They proposed two categories of evaluation criteria, Interface Usability and Didactic effectiveness. The heuristics were validated through evaluations of two LMS: the Moodle-based system at the University of Dar es Salaam and the Shuledirect platform for secondary school students. These evaluations uncovered numerous usability problems, particularly in terms of didactic effectiveness. The authors concluded that their proposed heuristics were effective in identifying usability issues specific to African LMS implementations and emphasized the need for institutions to conduct usability evaluations before adopting LMS.

In this paper[35], the authors developed a set of heuristics that were specifically tailored for evaluating dashboard visualizations used in clinical settings. They recognized that while Nielsen’s ten usability heuristics are widely applied for general interface evaluation, they do not adequately address the unique challenges posed by information visualization systems. To develop their heuristic checklist, the authors combined Nielsen’s principles, with heuristics specifically designed for information visualization, based on previous work by Forsell and Johannson. They structured a consensus-building process known as the nominal group technique, engaging with 12 informatic experts from various healthcare disciplines to refine the set of heuristics. These experts were asked to rate and provide feedback on the importance of each proposed heuristic, leading to a final list of 10 usability principles, including seven general and three specific to information visualization. The checklist was then ap-

plied to a clinical dashboard that summarized vital sign data for home care nurses. Three nursing informatics experts used the checklist to evaluate the dashboard, identifying usability issues primarily to user control and freedom, and flexibility and efficiency of use. The feedback validated the utility of the checklist, proving its effectiveness in identifying and categorizing usability problems within the domain of health information systems that use visualized data displays.

In this paper[39], the author describes how Nielsen’s usability heuristics fall short in modern systems, even though they are considered the de facto standard in the process of usability heuristics. Hence, the authors developed a set of heuristics specifically designed for evaluating virtual learning environments (VLE’s) using the PROMETHEUS methodology. For VLE systems, Nielsen’s heuristics do not fully capture the challenges, to address this gap, the authors applied the PROMETHEUS framework to create a domain-specific set of heuristics tailored to VLE’s. The process involved adapting general usability principles and creating new heuristics that addressed the unique needs of educational platforms. The authors engaged a group of 35 evaluators, who were tasked with evaluating a VLE using both the newly developed VLE heuristics and Nielsen’s heuristics. This comparative analysis allowed a thorough assessment of the new heuristics, revealing that the VLE specific set was more effective at identifying usability problems. The feedback from the evaluators confirmed the utility of the VLE heuristics, demonstrating their ability to address issues that Nielsen’s heuristics often overlooked, such as the flexibility of learning resources and the adaptation of content across different devices.

In this paper[46], the authors developed a set of user experience heuristics specifically for evaluating e-commerce websites called ‘ECUXH’. Their aim was to address limitations in general usability heuristics, like Nielsen’s which does not fully capture the unique challenges of e-commerce platforms. The authors followed a structured process to create these new heuristics, adapting previous research and incorporating elements from both general usability principles and e-commerce specific requirements. They had started by reviewing existing heuristics, and identified areas where these sets of heuristics fell short in the e-commerce domain. The authors then had refined these heuristics through an iterative process, gathering data from case studies and experiments to inform the final set. What sets ‘ECUXH’ apart is its emphasis on factors beyond usability, such as transaction reliability, user control, and payment options, which are all critical for online shopping environments. However, the paper also highlights some issues that they had incurred during the development process. While the authors used a comprehensive methodology, they noted that existing heuristics were inconsistent in how they approached e-commerce evaluation, leading to a need for significant adaptation. Additionally, the validation of these heuristics was done through three evaluation methods: heuristic evaluation, user tests, and expert judgement. The results showed that ‘ECUXH’ had identified more usability problems than the general heuristics, but the validation process mainly relied on expert feedback, which may introduce some bias and was acknowledged by the authors.

## 2.2 Background

### 2.2.1 Human Computer Interaction (HCI)

Human Computer Interaction (HCI) has its roots starting at 1969 when ACM formed the Special Interest Group in Social and Behavioral Computing (SIGSOC) with the initial focus on social sciences [53]. However, over time focus shifted to user behaviour and needs with focus on the human aspect of computing. As a result, SIGSOC changed to Special Interest Group on Computer-Human Interaction (SIGCHI) in 1982. It could be said that HCI was officially born in 1983 due to the first ACM SIGCHI conference, the publication of Card, Moran and Newell's the Psychology of Human-Computer Interaction and the announcement of the Apple Macintosh. Edmonds has likened Human Computer Interaction similar to interactive digital art. Interactive digital art focuses on interactive experience. As a result, it can be inferred that HCI is very similar to experience design. Initially starting out as a branch of computer science, HCI has grown to be an interdisciplinary field spanning a much larger field of science, technology and art [21]. In order to further improve the interaction between user, it is therefore necessary to understand the user and how their engagement to the product or task is relevant. So, it can be said the HCI is a the process of designing, implementing and evaluating a product, which, in this case, would be the user interface. Moreover, in order to do so, it is necessary to take into account the user in this process. With time, newer approaches have arisen to better understand and evaluate HCI. According to Nielsen [1], these ways include a form of analysis technique which requires analysing user interfaces critically to find their flaws, an automated procedure which could be the fastest but is infeasible since technology is evolving at a fast pace as well as the difficulty to automate or fully understand human behaviour, testing empirically by actual users which might be the most time-consuming and expensive but provides the most accurate results as well, and a heuristic approach consisting of experts who would make decisions by looking at the interface and passing judgements based on their opinion.

### 2.2.2 Heuristic Evaluation

As stated by Nielsen, heuristic evaluation is the process of looking at an interface and trying to decide what is good or bad about the interface [1]. This is often done by following a set of rules or guidelines provided in a document. Prior to the creation of Nielsen's list, people would evaluate heuristics based on their intuition and common sense. Heuristic evaluation is also the most widely used usability evaluation methods since it is cheap and the results can be obtained much faster than other evaluation methods [34]. It is often done by a small group of evaluators who are often experts in the field of usability [30]. However, with recent developments, a larger number of non-experts may even be included if access to experts are a bit problematic [47]. Initially, the evaluators would evaluate the provided user interface alone and pass judgements. Once they have finished pointing out problems in the interface, the evaluators would then gather around to discuss all the problems they have detected. Finally, they would then try to brainstorm ways in order to fix each usability problem one at a time and finally apply the fixes to the design. However, applying the design is simply not the end. With improvements in technology and constantly changing user tastes, designs need to be updated over time. As a result, heuristic evaluation

becomes an iterative process and so could also be a cheap method when we try to heuristically evaluate multiple designs to come up with the best one in order to continuously improve upon the design. Initially, this list consisted of following Nielsen's list which consisted of 10 rules for designing user interfaces. However Nielsen's heuristics have been heavily criticised as some studies have reported that it focuses on the system literally rather than focusing on the user experience leading to inaccurate results [50]. As a result, many researchers have focused on creating newer heuristics by extending Nielsen's heuristics to fix these issues or focus on moving to domain-specific heuristics since Nielsen's heuristics cannot be generalized to all types of websites.

### 2.2.3 User Testing

According to Riihiaho, user testing is a formal method of determining and designing test goals, conducting the test sessions and analyzing the tests and their results and finally reporting the findings to the development team [8]. Successful usability testing entails planning, designing, and conducting tests, recruiting participants, analyzing results and recommending improvements. The test plan consists of a list of tasks that the participants would perform on the user interface to later report on. It could be provided on a checklist or a form while the user is working on it. The participants should generally represent the target demographic of the people that would actually use the interface which otherwise might lead to a poor evaluation of the user interface. In the case of websites, it would not be necessary to create a room along with the necessary equipment as most of the equipment used by the people are easily accessible nowadays. The observation of the results could be received from the participants in multiple ways including form submissions, interviews, etc. The results of these would then be passed to the team responsible for the interface design to bring on further changes. This process is repeated to further improve the usability of the interface.

### 2.2.4 Systematic Literature Review (SLR)

According to Stapic et al, Systematic Literature Review, or SLR, is the process of assess and explain all present research that is relevant to a specific research question or topic of interest [15]. In order to do so, we would have to follow a procedure or steps that has been provided in the SLR to reach a conclusion. Following SLR, prevents us from reaching the wrong conclusion which may arise due to biases in the review process or in the literature itself from where we might extract the data. Despite being created by adapting techniques from various disciplines, mainly focusing on medicine, SLR can also be applied to fields of computer science. Its most common use case is to condense all available information regarding a topic from already existing research on the selected topic. The methodology created by Keele has 3 phases along with their respective sub phases that are given below[6]:

#### 1. Planning the review

- **Identification of the need for a review:** Before performing a systematic review, it is necessary for researchers to ask themselves whether a systematic review is even needed. An assessment criteria should be used

such as a checklist consisting of the inclusion and exclusion criteria to analyse a topic

- **Commissioning a review:** Sometimes organizations require information regarding a certain subject but have lackings thereof. As a result, they may pay researchers to perform the systematic review in their place through a commissioning document containing information regarding the process to be followed. This step is optional and unneeded if the research is done for one's own needs or by a single PhD student.
- **Specifying the research question(s):** These questions are the focal point of SLR by ensuring that the search strategy identifies the required primary studies, extracting the data needed from the selected studies to provide solutions to previous questions by synthesizing data in specific process. The questions formed should be meaningful and important to researchers, bring changes to current practices or increase the value of a certain practice and will provide a new outlook on the research. The structure of the question should be such that it should take into consideration:
  - **Population:** The group of people that are affected by the research method
  - **Intervention:** It is a software procedure to address an issue
  - **Comparison:** This is the software procedure that the newly created procedure will be compared with. If this procedure is commonly-used technology or the industry standard, it must be explained in detail.
  - **Outcomes:** It should be a connection to factors that are important to those impacted by the research by ensuring increased efficiency
  - **Context:** It is the environment under which people perform tasks to ensure accurate comparison of two methods. Often this is done in an academic setting using students as participants and might not be representative of what is done in the industry
- **Developing a review protocol:** It details the methods needed to undertake a specific systematic review and reduce bias. This review consists of all the information needed for the review as well as the dissemination strategy, the project timetable focusing on previously setup conditions
- **Evaluating a review protocol:** This process is recommended but may not be done. Researchers must come to agreement on an evaluation criteria for evaluating their developed protocol by taking into consideration various aspects such as the purpose of the research, the desired quality, the time needed for the research, the allocated budget, etc.

## 2. Conducting the review

- **Identification of Research:** In this process, it is necessary to determine and follow the search strategy that was developed earlier on to find studies relevant to the research's subject of interest while ensuring that this information is transparent and is documented. It is also necessary to create a list of similar search keywords to ensure more primary studies can be accessed. It is also necessary that electronic databases are used as

well as other sources such as publishers or bibliographic databases. It is important to ensure that multiple databases are searched from since all the information may not be in a single database.

- **Selection of Primary Studies:** Applied on all resulting papers from our search strategy and evaluated using the inclusion and exclusion criteria in order to decide which of them are applicable. The inclusion and exclusion criteria should be made based on the research questions as well as practical issues. The inclusion criteria should define which studies to include while the exclusion criteria should be applied on the collected papers to remove studies that are irrelevant to the research. The selection process should focus on the title, abstract and conclusion when deciding to include or exclude literature.
- **Study Quality Assessment:** Based on the quality of the paper, the data is documented. A checklist should be utilized to evaluate the quality of the studies based on multiple factors.
- **Data Extraction and Monitoring:** The aim of this stage is to accurately extract information of all the information researchers collected from the previous papers while ensuring that none of this information is biased. Content that should be extracted should include:
  - Reviewer’s name
  - The day, month and year the data was collected
  - Major information of the paper
  - Space for remarks and comments

If possible, this stage should be done by 2 or more researchers after which the information among all researchers should be compared and any disagreements should be resolved by reaching an agreement or by through the arbitration of a single researcher working without depending on anyone.

- **Data Synthesis:** The focus of this process is to collect the extracted data and summarize it in an appropriate manner while preventing duplicates. 2 types of data synthesis methods are utilized in SLR: descriptive and quantitative. In order to achieve reliable conclusions, the rationality of the evidence and how frequently it occurs should be considered. The merging process starts with condensed information from earlier papers. Collected data are organized in a tabular form based on the similarity of their results.

### 3. Reporting the review

- **Specifying dissemination mechanisms:** This stage is carried out when the task is offered to someone else based on a payment contract or if it was not offered up at all. These dissemination activities should focus on publishing information in such a way that it is transparent and available to others
- **Formatting the main report:** Systematic reviews should be reported in 2 formats: as a thesis for the PhD stage, or as a published paper.

A journal will have a limited number of pages so all information cannot be provided in it. So, in order to ensure complete transparency and ensure the validity of the research, the technical report or thesis should be provided as a reference to the journal or conference paper.

- **Evaluating the report:** If the information is provided in a journal, it should be peer reviewed before passing on the information while PhD theses are evaluated by experts as part of an examination. For, technical reports, an expert panel or several other experienced researchers should evaluate the report.

## 2.2.5 Rusu's methodology

According to Rusu, recently there has been increased focus in evaluating usability of applications that were formed due to breakthroughs in technology. However, traditional heuristics were not sufficient and accurate in evaluating the usability of these applications which is why it became important to create new heuristics. However, there was no methodology to develop such heuristic so Rusu adopted a 6 step approach for creating new heuristics[11]:

1. **Step 1: An exploratory stage** - This stage focuses on collecting primary studies related to the main topic of the research. This may include specific applications, properties of these applications and similar usability heuristics if they exist.
2. **Step 2: A descriptive stage** - The aim of this stage is to extract the most relevant information from papers or studies found in the exploratory stage and highlight the most important characteristics of the extracted data. This would often involve collecting necessary heuristics from the primary studies, match the definition with heuristics from other sets and finally review each other's work. If no heuristics are found for the specified domain, Nielsen's 10 heuristics could be used.
3. **Step 3: A correlational stage** - The aim of this stage is to find properties that the usability heuristics for the application or domain should possess based on previous heuristics and investigation of case studies. In this case, we will try to map known usability flaws to our usability heuristics. This would show how many usability flaws can be mapped to the current set as well as finding the number of flaws that cannot be mapped to any heuristics.
4. **Step 4: An explicative stage** - This stage aims to formally every heuristic based on a certain format so it can be documented. This template consists of:
  - **ID, Name and Definition:** An identifier for the heuristic, its name and definition.
  - **Explanation:** An explanation focusing on usability guidelines with sources, how they are violated and suggested similar heuristics that were brought forward by others.
  - **Examples:** An example of how the heuristic violates a principle.

- **Benefits:** The benefits that can be expected due to the creation of this heuristic.
  - **Problems:** The types of misinterpretation of the provided heuristic that can be expected when performing heuristic evaluation.
5. **Step 5: A Validation Stage** - The purpose of this stage is to validate the set of newly created heuristic set against another existing set of heuristic though conducting experiments. These experiments often consist of performing heuristic evaluation on a selected case study or by user tests.
  6. **Step 6: A Refinement Stage** - The heuristics may be further improved through modified definitions, better phrasing or inclusion and exclusion of currently existing heuristics using the feedback that was received from the fifth step.

There is no need to follow these steps strictly and so steps can be repeated multiple times depending on the heuristic developer's cases. Since most of traditional heuristics solve generalized problems, this set of heuristic can used to add specific heuristics to a generalized heuristic in order to make the heuristic more complete for that set.

# Chapter 3

## Methodology

For this paper, we have decided to modify Rusu's methodology[11] to ensure that heuristic development for multiple domains can be done. Two additional stages were added along with a loop to ensure that heuristics can be developed for multiple domain. Since we are working on websites, a good number of heuristics have been developed in order to ensure that users have a pleasant experience using the website. Hermawati[26] reported that based on all newly developed heuristics, 80 percent consisted on extending upon Nielsen's heuristics. So, the initial steps consist of selecting a base heuristic that will be extended upon in later steps. This is because most of the heuristics developed for any website, mobile device, application or even user interface has often been built up on Nielsen's heuristics[54]. However, it is not necessary to use Nielsen's as the base heuristic. There are often other heuristics such as those of Tognazzini's Principles of Interaction Design[55], Schneiderman's 8 Golden Rules[9] and Bastien and Scapin's Ergonomic Criteria for Evaluation of User Interfaces[4]. A combination of these heuristics can also be used for this stage. The steps for this process are described later on. The next step continues on from the exploratory stage of Rusu's methodology until it reaches the explicative stage. Depending on whether the development of heuristics for all domains has been complete, the next step would be moving on to the validation stage or returning to the exploratory stage for the new heuristic. However, according to Hermawati[26], out of the 70 papers on the development of usability heuristics, only 19 focused on evaluating them and even among those 19 papers not all performed comparison with other heuristics. Therefore, an evaluation stage has been added to the stage where we evaluate and compare the set of heuristics with another based on a criteria. An updated explanation of each stage is provided below:

1. **Selecting a Base Heuristic:** For this stage, a set of heuristics that already exist should be used and extended to develop new heuristics to avoid sorting them into initial groups and removing duplicates. In order to perform the combination, the methodology proposed by Granollers[36] was used. The methodology described in brief is given below:
  - Revision of the two given lists are done where the researcher would read up the heuristics from each set and try to understand the meaning of each heuristic.
  - Compare similarities so that multiple heuristics can be merged to obtain a compressed and complete set of heuristics for evaluating user interfaces.

- Integrate the similarities to obtain the final set of heuristics for user interface evaluation.

If however, no such previous base heuristic does not exist or is inapplicable for the given domain, this step should be skipped and heuristics should be developed from the next stage.

2. **Exploratory Stage:** Similar to Rusu’s methodology this step requires collection of primary studies that are related to the main topic of the research. However, a search strategy has been incorporated along with an inclusion and exclusion criteria based on the Systematic Literature Review Method. This search strategy and inclusion and exclusion criteria must be applied on appropriate data sources to get accurate results. Quality assessment is also done to remove the papers that are not deemed relevant.
3. **Descriptive stage:** The aim of this stage is to extract the most relevant information from the primary studies that were collected in the exploratory stage. A criteria or set of rules should be developed for the type of information to extract for each stage. A reviewer could be used to decide if a heuristic should be kept or removed which in our case consisted of researchers other than the one who extracted the information. This stage ensures that none of the information extracted are duplicates of each other.
4. **Correlation stage:** The aim of this stage is to understand the problems that were extracted in the previous stage and try to map them to the base heuristics that have been chosen. This process would help in identifying heuristics that cannot be mapped for the development of new heuristics.
5. **Explicative stage:** The remaining usability issues that remain will be used to form new heuristics. However, no approach is explained on how these heuristics will be developed so we have adopted thematic analysis which is a qualitative analysis method[40]. The steps to perform thematic analysis is given below:
  - **Familiarizing with data:** In this step, we reread the usability problem and try understanding it. A discussion was carried out with the rest of the members of this paper to form a better understanding of these problems.
  - **Generating initial codes:** This process requires us to generate a code, similar to a short title, which can be used so that we can develop themes. A table is used to record each code along with their respective explanation to form a clear understanding of it. This step also helps us to remove duplicate codes or usability problems that focus on the same issue so that only distinct codes remain in the sorting phase.
  - **Searching for Themes:** In this stage we start forming the themes by sorting the codes into specific groups. These groups are what we call themes. Similar to Kumar et al, we used visuals to aid our grouping strategy. This process would give us a list of themes without any specific name.

- **Defining and Naming Themes:** This step is used to focus on the meaning of each theme that has been generated. An explanation is generated for each theme which would try to be as concise as possible while making the theme as easily understandable as possible for the reader.

If the development of heuristics has not been done for all domains, we return to the second stage of the heuristic development process where we continue the process from the start with our base heuristic being the previous base heuristic and the newly developed heuristics that have been generated following thematic analysis. If, however, the heuristics have been developed for all domains, it is possible to move onto the validation stage. In case, no base heuristics were chosen at the first step, the heuristics developed at this stage should be utilized.

6. **Validation Stage:** In this stage, we perform user tests on similar websites for both personal computers and mobile and use the data to observe if we are missing any heuristics. The purpose of utilizing user tests is primarily because users will be the ones to use the website so it is necessary that the heuristics created can cover the problems they might face.
7. **Refinement Stage:** Based on feedback from the validation stage, the heuristics may be updated through modification or renaming them so that they may be easier for evaluators to understand. The heuristics refined at this stage are documented based on the template provided by Rusu's methodology as given below:
  - **ID, Name and Definition:** An identifier for the heuristic, its name and definition.
  - **Explanation:** Heuristic's detailed explanation, including references to usability principles, how they violate common usability problems and related usability heuristics proposed by other authors.
  - **Examples:** An example of how the heuristic violates a principle.
  - **Benefits:** The benefits that can be expected due to the creation of this heuristic.
  - **Problems:** The types of misinterpretation of the provided heuristic that can be expected when performing heuristic evaluation.
8. **Evaluation Stage:** Similar to the Systematic Literature Review, it is necessary that we provide a form of evaluation for our approach. An evaluation stage is incorporated into the methodology because despite the refinement, it is necessary to know what the evaluators think of the heuristic after using them based on a comparative study with another heuristic set, preferably one that is currently used for such domain. In our case we have decided to utilize interviewing users and observing what they deem as problems as well as using a specific criteria to evaluate the two sets of heuristic with each other.

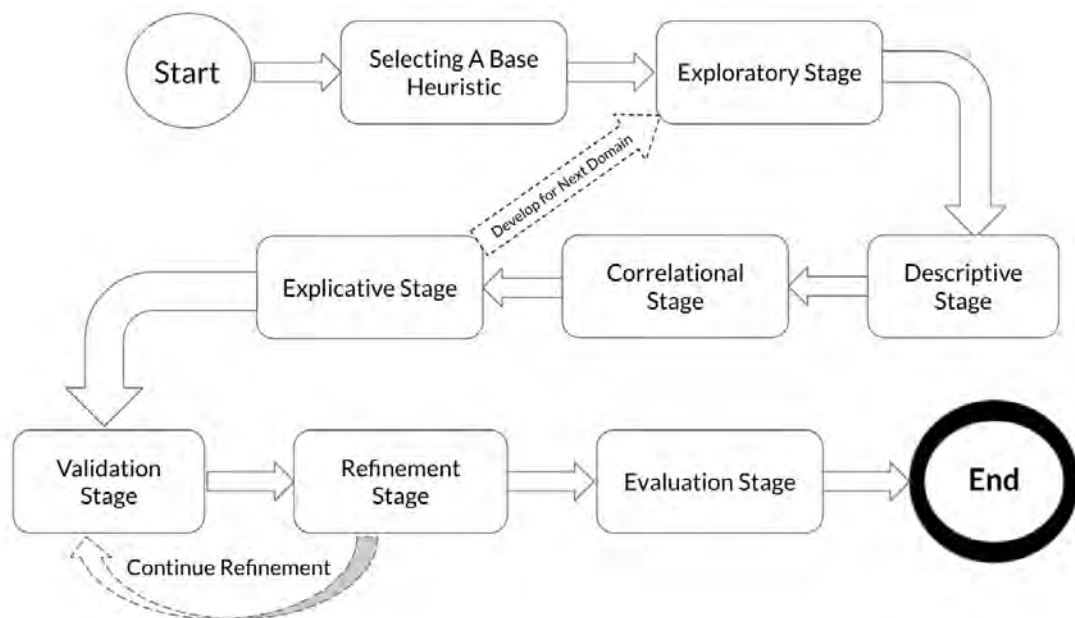


Figure 3.1: Usability Problems per heuristic

# Chapter 4

## Data Analysis and Results

### 4.1 Stage 1: Selecting a Base Heuristic

Since, we are working on web interfaces, the most commonly used heuristics could be any one of or a combination of Nielsen's heuristics[54], Tognazzini's Principles of Interaction Design[55], Schneiderman's 8 Golden Rules[9] and Bastien and Scapin's Ergonomic Criteria for Evaluation of User Interfaces[4] can be used. Nielsen's heuristics cover a lot of problems and are often used as the base in most heuristics, however, in our case, we have decided to merge Nielsen's and Tognazzini's heuristics due to Nielsen's being the most used heuristic set in the industry and due to Tognazzini's being the most expressive[36]. Nielsen's heuristics have been retrieved from the website of the Nielsen Norman Group's website with the additional tips being added to the explanation in 2020[54]. Tognazzini's heuristics were also retrieved from his website with the updated principles for each heuristic[55]. Taking Nielsen's as the base we initially tried to see if any of the heuristics name overlap, if they do so, we would simply merge the heuristics and take all distinct sub-heuristics or principles that were provided for each heuristic.

Tognazzini's heuristics, Aesthetic, and Color, were added to Nielsen's Minimalist and Aesthetic Design with their distinct tips being taken in together since both of them focused on the same set of principles. Tognazzini's heuristic Anticipation was merged with Nielsen's Help and Documentation since the heuristic simply had 1 principle which emphasized providing all information and tools to the user when needed which already existed in Nielsen's Help and Documentation. The principle's of Tognazzini's heuristic Autonomy was added to Nielsen's User Control and Freedom since both heuristics served the same purpose. The Consistency heuristic of Tognazzini was added to Nielsen's Consistency and Standards along with its principles. The heuristics, Defaults, Efficiency of the User and Fitts' Law had principles in Tognazzini's heuristics that focused on the same set of rules as Nielsen's Flexibility and Efficiency of Use so the rules were merged along with their principles or tips. Tognazzini's Explorable Interfaces had principles that were part of Nielsen's User Control and Freedom along with his Discoverability heuristic so the principles were added to the specific heuristics. Tognazzini's Metaphors, Use of had the same explanation and principles as that of Nielsen's Match between System and Real World so the principles were added to Nielsen's heuristic, Match between System and Real World. Tognazzini's Protect Users' Work was added to Nielsen's Error Prevention

heuristic. Tognazzini’s Learnability and Simplicity were merged together to be a new heuristic Learnability and Simplicity with all of their heuristics intact. Tognazzini’s State: Track it was merged with Nielsen’s Visibility of System Status since both of them focused on the use of feedback and making the information visible to the user. Tognazzini’s Visible Navigation was made a part of his Discoverability heuristic and Nielsen’s Flexibility and Efficiency of Use since it had only two principles with one focusing on ensuring that one could find the links easily and the other ensured that screen counts were limited through the use of overlays and modals. A table is given to better visualize this information with multiple Tognazzini’s heuristics separated by a semi-colon and heuristics that were split marked with a (i) and (ii) to represent their divided parts.

Table 4.1: Process of Merging Nielsen and Tognazzini’s Heuristics

| Nielsen’s Heuristic                                     | Tognazzini’s Heuristics                                                      | Merged Heuristics                                       |
|---------------------------------------------------------|------------------------------------------------------------------------------|---------------------------------------------------------|
| Visibility of System Status                             | State: Track it                                                              | Visibility of System Status                             |
| Match Between System and Real World                     | Metaphors, Use of                                                            | Match Between System and Real World                     |
| User Control and Freedom                                | Autonomy; Explorable Interfaces <b>(i)</b>                                   | User Control and Freedom                                |
| Consistency and Standards                               | Consistency                                                                  | Consistency and Standards                               |
| Error Prevention                                        | Protect Users’ Work                                                          | Error Prevention                                        |
| Recognition Rather than Recall                          |                                                                              | Recognition Rather than Recall                          |
| Flexibility and Efficiency of Use                       | Defaults; Efficiency of the User; Fitts’s Law; Visible Navigation <b>(i)</b> | Flexibility and Efficiency of Use                       |
| Aesthetic and Minimalist Design                         | Aesthetics; Color                                                            | Aesthetic and Minimalist Design                         |
| Help Users Recognize, Diagnose, and Recover from Errors |                                                                              | Help Users Recognize, Diagnose, and Recover from Errors |
| Help and Documentation                                  | Anticipation                                                                 | Help and Documentation                                  |

|  |                                                                    |                             |
|--|--------------------------------------------------------------------|-----------------------------|
|  | Discoverability; Explorable Interfaces(ii); Visible Navigation(ii) | Discoverability             |
|  | Human Interface Objects                                            | Human Interface Objects     |
|  | Latency Reduction                                                  | Latency Reduction           |
|  | Learnability; Simplicity                                           | Learnability and Simplicity |
|  | Readability                                                        | Readability                 |

The base heuristics are given below:

1. Visibility of System Status
2. Match Between System and 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
11. Discoverability
12. Human Interface Objects
13. Latency Reduction
14. Learnability and Simplicity
15. Readability

## 4.2 Mobile Device Heuristics

This section elaborates the data collection, the data extraction, data correlation and the heuristic development process for mobile devices. Since the stages are repeated from 2 to 5 for each specific domain, the stages are repeated for each domain until the heuristic development for all domains are complete.

### 4.2.1 Stage 2: Exploratory Stage

As stated by SLR[6], in order to collect data, it is necessary to use appropriate sources to collect data from and so we used sources that are most used in computer science research. We searched the database of IEEEExplore, ACM Digital Library, Springer Link and Google Scholar. Rather than searching on a single database, it is necessary to use multiple sources since all the information regarding heuristics will not be stored in a single database. The keywords used for the search consisted of: Mobile usability issues, Smartphone usability issues, Mobile usability heuristics, Smartphone usability heuristics, Mobile heuristic evaluation, Mobile usability testing, Mobile heuristics. Abbreviations of the words along with their synonyms were used to make the search as appropriate as possible. Moreover, prior to deciding which papers to select it is also necessary that we create a criteria for including or excluding papers which leads us to the inclusion/exclusion criteria.

The inclusion criteria consisted of the following rules:

1. The paper has explanation of mobile usability issues
2. The paper contains mobile usability heuristics
3. The paper was published between 2012 and 2024

The exclusion criteria consists of the following rules:

1. Language of the paper is not English
2. The paper focuses too deeply on another domain application of mobile devices rather than the device itself

Following any single rule of the exclusion principle would ensure that the paper in question would be excluded from the list. And so, following these criterion we selected 16 papers out of which we further removed 6 of them after skimming through them since many of them were not relevant to our purpose. The remaining 10 were then used for data extraction process. The papers rejected are given below:

- Locating Usability Critical Factors for Mobile Applications Using ELECTRE-TRI Method[37]
- A quantitative evaluation of usability in mobile applications: An empirical study[32]
- Usability Heuristics Validation through Empirical Evidences: A Touchscreen-Based Mobile Devices Proposal[14]
- Mobile Applications Usability Evaluation: Systematic Review and Reappraisal[49]
- Usability dimensions for mobile applications-a review[16]
- Usability guidelines of mobile learning application[17]

The papers that were selected are provided below:

- Usability Heuristics for Mobile Learning Applications[40]

- Usability of Mobile Applications: A Systematic Literature Study[45]
- Usability Heuristics for Touch screen mobile devices[13]
- Usability Heuristics For Touchscreen-based Mobile Devices: Update[19]
- Set of Usability Heuristics for Quality Assessment of Mobile Applications on Smartphones[41]
- A systematic literature review of mobile application usability: addressing the design perspective[51]
- EUHSA: Extending Usability Heuristics for Smartphone Applications[38]
- A Review on Usability Issues in Mobile Applications[28]
- Developing SMASH: A set of SMARtphone’s uSability Heuristics[27]
- Newly Developed Heuristics to Evaluate M-Learning Application Interface[43]

### 4.2.2 Stage 3: Descriptive Stage

For this process, we decided to only extract information that was either a usability issue with some form of explanation or part of the explanation of a heuristic from the developed set of heuristics among the selected literature. Based on this data, we discovered that there were a total of 70 usability problems from all our present literature. After accounting for duplicates, 44 of these problems remained. These 44 problems elaborated on existing mobile usability issues that plagued users when they tried to use the web on their device. A list of these problems are provided below:

- Prioritize selection over typing or data entry.
- Minimize number of clicks
- Ensure interactive features are visible and user-friendly
- Allow users to zoom in and out according to their preferences
- Incorporate visuals, icons, sounds, text color, backgrounds, and animations to aid learning.
- Decrease the number of taps needed for app usage
- Minimize the frequency of back button usage
- Reduce the need for assistance during first-time tasks
- Simplify the number of gestures needed to reach a target
- Keep the time taken to find buttons for specific actions low and straightforward
- Hide or disable unavailable functions while providing additional information about available options
- Use of sound, vibration and lights for feedback

- Ensure that all interactions among the user, system, and environment occur simultaneously; avoid distractions
- Address low screen resolution that can impair multimedia quality and lead to usability issues
- Present visible objects, actions, and options to eliminate the need for users to memorize information across different parts of the interface
- Offer both basic and advanced configuration options, enabling users to define shortcuts for frequent actions.
- Ensure the device loads and displays information quickly, minimizing task steps and allowing for smooth animations
- Position buttons in recognizable locations based on users' experiences with similar applications
- Increased target size (Not necessarily text size)
- Users must adapt to new norms and relearn meanings, actions, and terms when using smartphones
- Provide feedback when it would be needed by the user even if the user is not using it
- Smartphone should provide the UI layout with adequate margins and recognizable placements for ease of use
- Ensure the system delivers intended outcomes to prevent any input or output mismatches
- Enable frequent users to use shortcuts
- Offer informative feedback to users
- Foster a sense of control for the user
- Provide consistency across data formats
- Applications should be intuitive and easy for users to navigate without steep learning curves
- Allow users to quickly grasp how to use the app, even with minimal experience
- The app should meet user expectations and provide a satisfying experience.
- Apps should cater to a broad audience, considering physical limitations and the need for clarity in design.
- The app should cover topics or features comprehensively without overwhelming users.
- The app should accommodate a variety of users and their needs, offering options for customization where necessary

- The app's features, options, and navigation should be clearly visible and easily identifiable
- A consistent design helps users build familiarity and avoid confusion when interacting with the app
- Enhance the user experience with visually appealing designs
- Avoid forcing users to remember excessive information between steps to minimize errors
- Poorly placed buttons or physical interactions lead to discomfort or mistakes
- Menu or list selection should be used rather than navigation bar
- Content needs to be optimized so that it can be fit on the screen
- If content is large multiple screens can be used
- Number of menu levels should be small and simple
- Switching between the windows should not cause uneasiness
- Ensure there are no missing icons

### **4.2.3 Stage 4: Correlational Stage**

Out of the 44 given problems, 38 of them were mapped to our existing set of heuristics. In this case, we tried to familiarize ourselves with the list of issues and then tried to see which heuristic they can be added to if there were any. The following bar chart presents a count of the problems noted for each heuristic:

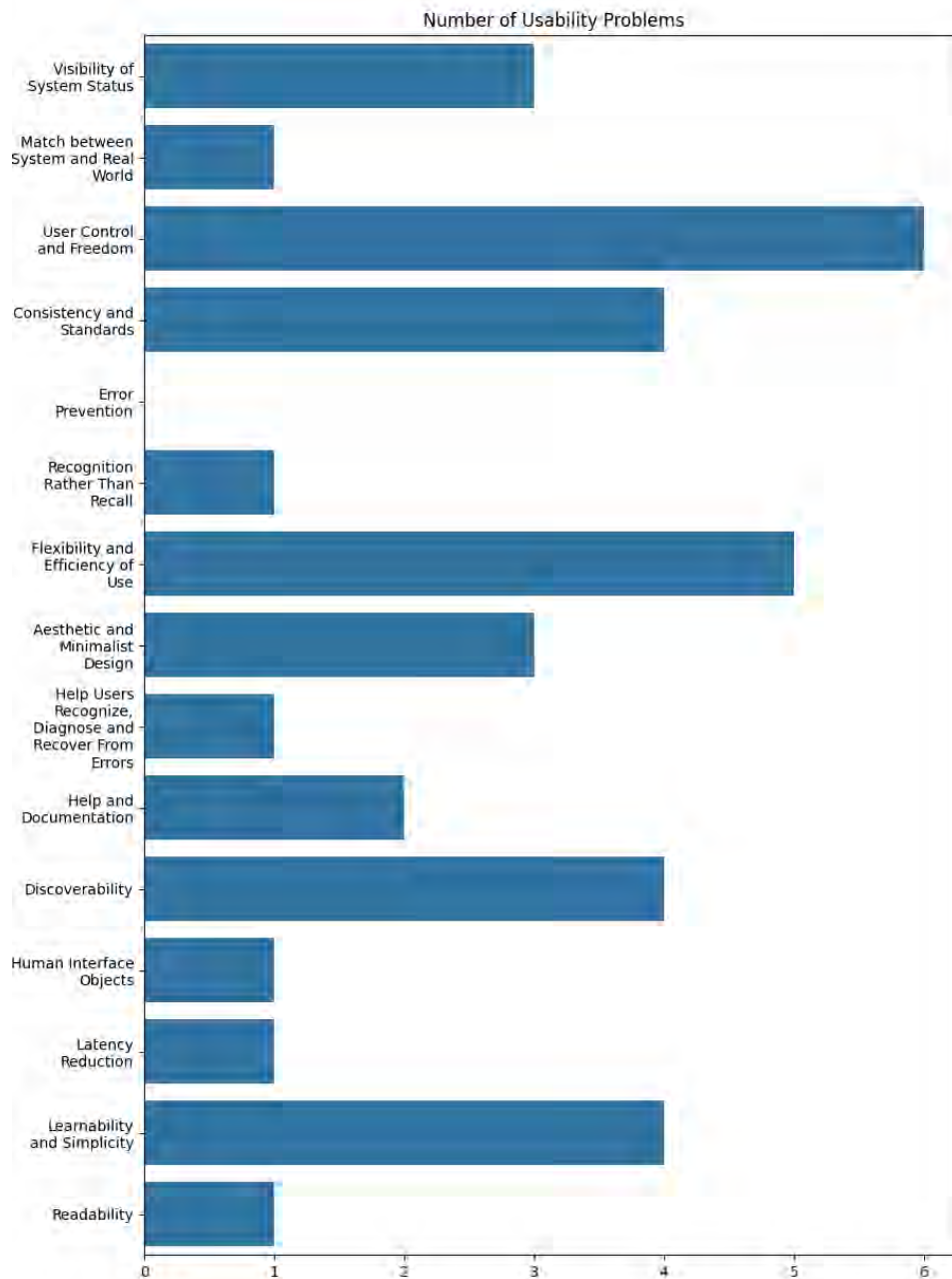


Figure 4.1: Usability Problems per heuristic for Mobile Devices

As we can see, most of the problems that were detected are connected to User Control and Freedom and Flexibility and Efficiency of Use. Moreover, it seems that the heuristics that were taken from Tognazzini's set also proved to be useful since there were problems related to Learnability and Simplicity and Discoverability. It would also seem that none of the heuristics have talked about Error Prevention

and so it might be better to merge the heuristics Error Prevention and Help Users Recognize, Diagnose and Recover from Errors to be a single heuristic. However, despite, most of the problems being mapped to our set of heuristics, not all the problems could not be mapped to our set. 6 of them still remain and so they will be used to develop new heuristics for our set of heuristics.

#### 4.2.4 Stage 5: Explicative Stage

For the mobile stage, we developed the following codes based on each usability problem following the rules of thematic analysis:

Table 4.2: Generated Code and Explanation of Mobile Usability Issues

| Code                    | Explanation                                                       |
|-------------------------|-------------------------------------------------------------------|
| List Selection          | Menu or list selection should be used rather than navigation bar  |
| Fit to Screen size      | Content needs to be optimized so that it can be fit on the screen |
| Use of Multiple Screens | If content is large multiple screens can be used                  |
| Few Menu Levels         | Number of menu levels should be small and simple                  |
| Easier Screen switching | Switching between the windows should not cause uneasiness         |
| Icons                   | Ensure there are no missing icons                                 |

Finally using the codes that have been provided, we developed themes by mapping these codes into groups and then naming the theme. An image is provided below on how this step was done:

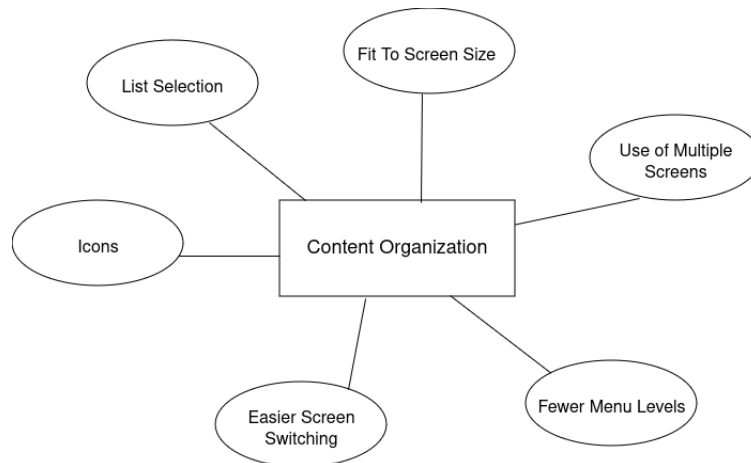


Figure 4.2: Codes and themes Generated for Mobile devices

An explanation of the newly created heuristic, Content Organization, is given below:

- **Content Organization:** The content should be organized such that the information can easily fit into screen of different sizes. For devices that are too small, a list navigation-like menu should be used rather than the navigation bar. However, the number of menu items should be low and easy to use. Necessary information should be organized such that they fit into the screen with the use of multiple screens if necessary to fit much larger content. Moreover, users should find it easy to switch between windows without disrupting their workflow. Necessary visual elements such as icons should also be present so that users do not miss out on crucial information.

With this set complete, the final set of heuristics for websites with access to mobile devices are given below:

- Visibility of System Status
- Match Between System and Real World
- User Control and Freedom
- Consistency and Standards
- Recognition Rather Than Recall
- Flexibility and Efficiency of Use
- Aesthetic and Minimalist Design
- Help Users Recognize, Prevent, Diagnose and Recover From Errors
- Help and Documentation
- Discoverability
- Human Interface Objects

- Latency Reduction
- Learnability and Simplicity
- Readability
- Content Organization

## 4.3 E-Commerce Heuristics

Using the heuristics created with mobile devices as the base, this section elaborates the process for creating new heuristics for E-commerce websites. The stages of data collection, data extraction, data correlation and heuristics development are repeated for E-commerce websites. The details of these stages are given below:

### 4.3.1 Stage 2: Exploratory Stage

For our sources, we utilized the databases of IEEEExplore, ACM Digital Library, Springer Link and Google Scholar. Moreover, the keywords used for the search include: E-Commerce heuristics, E-commerce usability issues, E-commerce heuristic evaluation, Heuristic evaluation for e-commerce websites, E-commerce usability testing. Similar words or synonyms have been used to aid in searching for more papers related to E-commerce websites. However, simply searching a database would result in a lot of irrelevant results so only those papers that have searched keywords of E-commerce or similar names such as M-commerce, Online shopping, etc., and emphasizes focus on usability or heuristics were chosen for the selection. The inclusion criteria focused on the following:

1. The paper provides an explanation of e-commerce usability issues
2. The paper was published between 2012 and 2024.
3. The paper focuses on mobile usability issues.

The exclusion criteria consists of the following rules:

1. Language of the paper is not English
2. A country specific E-commerce website usability paper has already been selected.

Based on these criterion, we have found 8 papers from which we further removed 3 papers after reading through them as many of them were irrelevant to our work or did not add anything new to it. The papers rejected are provided below:

- Exploring e-Commerce Usability by Heuristic Evaluation as a Complement of System Usability Scale[44]
- E-commerce websites for developing countries—a usability evaluation framework[18]
- Comparing Two Sets of Usability Heuristics in a User Experience Evaluation: A Case Study in an E-Commerce Mobile Application[52]

The papers that were chosen for data extraction are provided below:

- The Development of Usability Heuristics For Arabic M-Commerce Applications[42]
- ECUXH: A Set of User eXperience Heuristics for e-Commerce[46]
- A comparison of usability evaluation methods for evaluating e-commerce websites[12]
- A Set Of Heuristics for User Experience Evaluation in E-commerce Websites [20]
- Development of Heuristics for Usability Evaluation of M-Commerce Applications[31]

### **4.3.2 Stage 3: Descriptive Stage**

Similar to that of mobile devices, we decided to only extract information which clearly stated a usability issue or provided an explanation of its heuristics if it had any among the chosen literature. After reading through the selected literature, we discovered a total of 104 problems and after accounting for duplicates, 67 distinct problems remained. These problems were specific to e-commerce websites and are given below:

1. Most important components should be visible and understandable
2. Sense the users' fear of losing data (Moving to a new window or modal, in case, users fear they might lose their data. Use of feedback to tell users their data is saved. Use of recent items to view product that were not bought or have not been used in checkout)
3. Place the primary 'Add to Cart' button on each product page
4. Exercise caution when incorporating animated carousels.
5. Be mindful of adding images or product information across different sub pages
6. Pay attention to the layout and design of account-selection options
7. Make sure that the auto-correction feature is disabled when it is ineffective
8. Make sure that the fields are adequately sized to display common data
9. Navigation, should be intuitive, allowing easy movement between sections of the website
10. Category Hierarchy, clear and logical to help users to find products
11. Site Map, offer a quick view of the site's area/structure in a glance
12. Attention elements, usage of banners, sounds and animations to draw customer's attention

13. Value added information
14. Make the shopping cart accessible from all pages
15. Provide multiple delivery options to manage speed and cost
16. Offer a variety of payment options, such as credit cards, bank transfers, etc.
17. Maintain reasonable page and search response times
18. Interface consistency, ensure consistent style across the website
19. Use of attractive and innovative design to engage customers
20. Misleading links – Links with names that do not match the content of their destination page.
21. Non-obvious links – Links that are not situated in obvious locations on the website.
22. Weak navigation support – Pages without a navigation menu.
23. Pages with broken links – Links that lead to non-existent pages.
24. Orphan pages – Pages that do not have any links to other parts of the website.
25. Illogical categorization of information and products – Confusing menu structures.
26. Inappropriate page design – Layouts that confuse users, such as unclear login page designs.
27. Misleading images – Images used inappropriately, leading to user confusion.
28. Inappropriate font and color choices – Poor aesthetic design choices impacting readability.
29. Broken images – Missing or non-functional images on web pages.
30. Lack of clear error messages – Users not provided with appropriate feedback to recover from mistakes.
31. Missing internal search facility – Some websites lacked internal search altogether.
32. Absence of customer service sections – No access to customer support resources.
33. Inconsistent interface elements – Variations in design elements like buttons, colors, or font across pages.
34. Lack of sufficient feedback – The system did not provide clear feedback to guide the child toward correct actions.
35. Cluttered screen layout – The screen layout was not optimized for young children, making it visually overwhelming.

36. Inappropriate multimedia representation – Some multimedia elements (e.g., videos, sounds) did not contribute effectively to the learning process.
37. System and Transaction Status Visibility: The system does not always inform users about the current status of their transactions, leaving them unsure if actions have been completed or are still processing.
38. Mismatch Between the System and the Real World: Some e-commerce websites employ language or concepts that users find unfamiliar, hindering their ability to navigate and comprehend the process
39. Lack of User Control and Freedom: Users may not have enough control over their actions. For example, they may not be able to undo or redo steps easily, leading to frustration if they make mistakes.
40. Inconsistent Design and Standards: Websites may fail to maintain consistent design and terminology across different pages, confusing users as they navigate the site.
41. Poor Error Prevention, Recognition, and Recovery: Systems do not effectively prevent users from making errors, and when errors do occur, the error messages are unclear or do not provide enough information to help users recover.
42. High Memory Load for Users: Users are often required to remember information from previous screens or steps, increasing cognitive load and making it difficult to complete tasks efficiently.
43. Inflexibility and Inefficiency of Use: Websites do not always cater to both novice and experienced users. Some websites do not offer multiple ways to complete tasks, such as filters or shortcuts, making navigation inefficient.
44. Aesthetic and Minimalist Design Issues: Some e-commerce sites overload users with unnecessary information or clutter, detracting from the user experience.
45. Inadequate Help and Documentation: Users often struggle to find helpful information or documentation when they encounter problems on a site, as the help resources are not easily accessible or well-organized.
46. Transactions should be completed successfully
47. Transactions should be completed in time
48. Make sure each hit area and list item is clearly distinguishable
49. Category Hierarchy, clear and logical to help users to find products
50. Filters on category pages
51. Search box is set to be visible on top and appear consistent across all pages
52. Provide relevant search results
53. Checkout progress indicator at top of checkout page ( progress bar)

54. Multimedia resources to explain product ( pictures, videos, audio, animations)
55. Provide a product availability indicator
56. Provide all necessary information for decision making, ex: book details, price, availability
57. Product ratings and reviews, include external reviews to increase trustworthiness
58. Comparison tools to compare different products based on customer needs and costs
59. Clearly specify taxes, shipping and delivery information
60. Divide the checkout process into logical steps, ex: payment, order summary
61. Purchase Confirmation button, ensure the buy button is visible and accessible
62. Send confirmation email summarizing the order
63. Allow customers to track their order
64. Provide option to modify or cancel order including returns tracking
65. Include personalized elements like using customer names in communications
66. Website should provide various ways for customers to contact the company, ex: forms, email, phone to enhance customer confidence
67. Provide indication of product availability on product pages.

#### **4.3.3 Stage 4: Correlational Stage**

Out of the 67 problems, 45 of them were mapped to our current set of heuristics. After familiarizing with the issues provided, they were mapped to the heuristic they suited best if it was possible to add them to any. The frequency of the number of problems observed for each of the heuristic is given below:

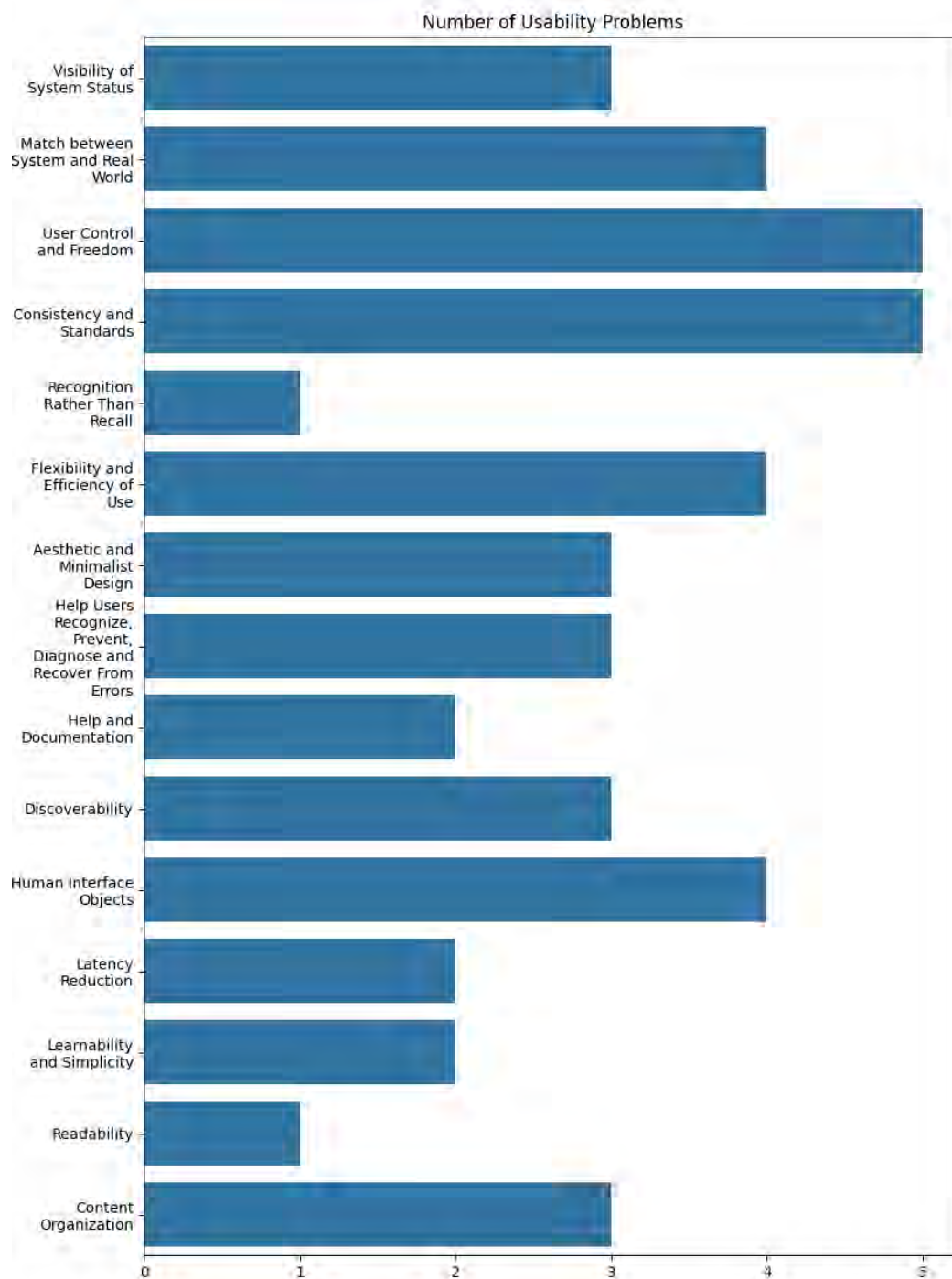


Figure 4.3: Usability Problems per heuristic for E-Commerce Websites

User Control and Freedom along with Consistency and Standards had the great-

est number of issues followed closely by Match Between System and Real World, Flexibility and Efficiency of Use and Human Interface Objects. Problems related to Recognition Rather than Recall and Readability seemed to be among the lowest as reported in the literature. However, not all of the heuristics could be mapped as they were domain specific and would require their own heuristics so that certain features would be given greater priority.

#### 4.3.4 Stage 5: Explicative Stage

Thematic analysis was applied to the remaining usability issues in order to generate codes. In order to ensure that data is not lost, a table is provided consisting of the code and an explanation of the usability issue each code refers to. This table is provided below:

Table 4.3: Generated Code and Explanation of E-commerce usability issues

| Code                             | Explanation                                                                                  |
|----------------------------------|----------------------------------------------------------------------------------------------|
| Successful Transactions          | Transactions should be completed successfully                                                |
| Timely Transactions              | Transactions should be completed in time                                                     |
| Product Selection area           | Ensure clear distinction of each hit area and list item                                      |
| Category Selection               | Category Hierarchy should be clear and logical to help users to find products                |
| Filter Results                   | Provide filters on category pages                                                            |
| Search box Consistency           | Search box is set to be visible on top and appear consistent across all pages                |
| Relevant Results                 | Provide relevant search results                                                              |
| Progress bar location            | Checkout progress indicator at top of checkout page                                          |
| Product Explanation              | Multimedia resources to explain product                                                      |
| Product availability indicator   | Provide a product availability indicator                                                     |
| Product information completeness | Provide all necessary information for decision making, ex: book details, price, availability |
| Product ratings                  | Product ratings and reviews, include external reviews to increase trustworthiness            |

|                                   |                                                                                  |
|-----------------------------------|----------------------------------------------------------------------------------|
| Product Comparison                | Comparison tools to compare different products based on customer needs and costs |
| Product information transparency  | Clearly specify taxes, shipping and delivery information                         |
| Checkout Process                  | Divide the checkout process into logical steps, ex: payment, order summary       |
| Purchase Confirmation Button      | Purchase Confirmation button, ensure the buy button is visible and accessible    |
| Product Confirmation              | Send confirmation email summarizing the order                                    |
| Order Tracking                    | Allow customers to track their order                                             |
| Edit Orders                       | Provide option to modify or cancel order including returns tracking              |
| Customer Communication            | Include personalized elements like using customer names in communications        |
| Multiple Communication Methods    | Website should provide various ways for customers to contact the company         |
| Missing product stock information | No indication of product availability on product pages.                          |

Using these codes, we developed themes by initially grouping the codes together and then giving that group a name. A visual representation of it is given in the next page:

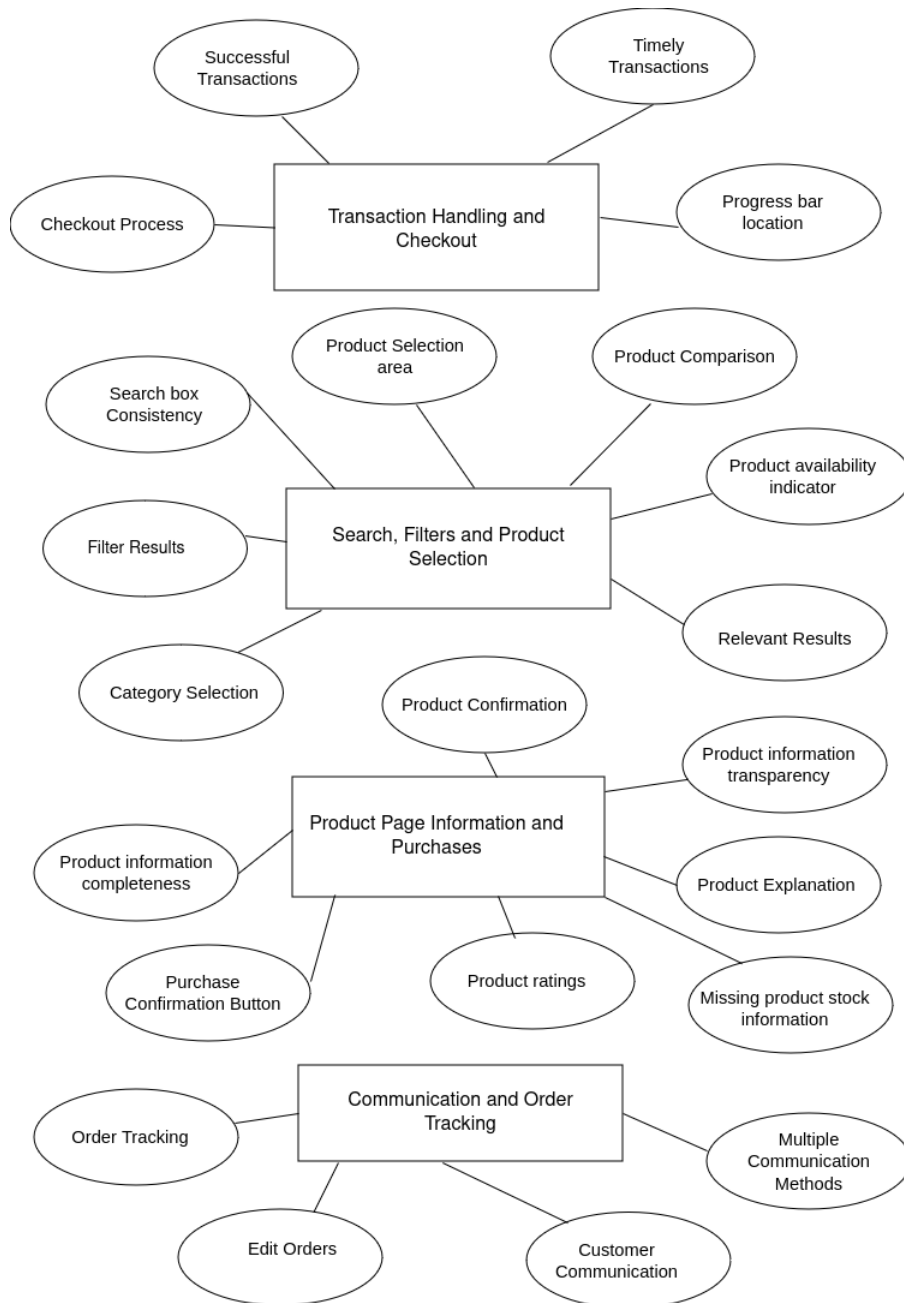


Figure 4.4: Codes and themes Generated for E-Commerce Websites

An explanation of the newly created heuristics are given below:

- **Transaction Handling and Checkout:** Ensure that transactions are completed successfully and in time. The checkout progress should be divided into multiple logical steps as well as provide a progress indicator at the top of the page.
- **Search, Filters and Product Selection:** Search box should be visible at the top of the page and should provide relevant search results. Search results should be filterable based on price, category and other criteria. The products on the search page should have an easy to grasp hit area as well as provide a product availability indicator. Tools should be provided to compare two or more items as well

- **Product Page Information and Purchases:** Product page should ensure all the necessary information are transparent to the user along with explanation on how to use it through images or videos. If a product is out of stock, the next date when it will be available should be provided. Reviews and ratings should also provided in order to ensure the quality of the product. A purchase confirmation button should be provided before the product is directly bought along with an email to the user summarizing the purchase.
- **Communication and Order Tracking:** Customers should be provided a one-to-one communication with the purchaser through multiple methods such as text, phone calls, etc. Moreover, orders should be made easy to track online through the website as well as the functionality to edit or cancel orders before the shipping process begins.

With the heuristic development process complete, the final set of heuristics for E-commerce websites with access to mobile devices are given below:

- Visibility of System Status
- Match Between System and Real World
- User Control and Freedom
- Consistency and Standards
- Recognition Rather Than Recall
- Flexibility and Efficiency of Use
- Aesthetic and Minimalist Design
- Help Users Recognize, Prevent, Diagnose and Recover From Errors
- Help and Documentation
- Discoverability
- Human Interface Objects
- Latency Reduction
- Learnability and Simplicity
- Readability
- Content Organization
- Transaction Handling and Checkout
- Optimized Search, Filters and Product Selection
- Product Page Information and Purchases
- Communication and Order Tracking

## 4.4 Stage 6: Validation Stage through User testing

The validation of the developed heuristics were done through user testing. Users were given a series of tasks to perform on 2 E-Commerce websites and based on these tasks, they would report any usability issues they could find. According to Nielsen[3], 5 users would be sufficient to find 80 percent of all problems, so we collected problems from 8 users for each website to find as many usability issues as possible. Before deciding on the tasks, we explored the given website to decide which tasks people were most likely to use. Once the exploration was complete, a form was created where users would submit the usability problems they have faced while completing the task. The tasks, that were provided in the form, consisted of logging into the website, searching for a specific product, finding more details about the product, adding it to the cart, proceeding to checkout, removing the product from the cart, using filters to sort the products, show products for a specific range, compare two products, updating the user profile, view order history, adding items to wishlist, accessing favorite items, checking out new offers.

Forms were set up that required the tasks to be completed and reported for both the mobile devices and the website. Results from the users were collected and after accounting for duplicates, a list of the problem is given below:

- Inaccurate search results
- Poor use of filters
- Search results cleared
- Out of stock products are shown first when filtering
- Difficult to sort items from highest to lowest price
- Out of stock items do not have price stated
- Difficult to compare items
- Difficult to add items to favorites
- Difficult to add items to wish list
- Poor contrast between font and background
- Text disappears when hovered over
- Lack of product details
- Difficult to find account information
- Difficult to understand what some icons mean
- Difficult to find locate certain buttons
- Lack of social authentication mechanisms

- Inconsistent design for smaller screens
- Difficult to distinguish between certain elements
- Favorites option disappears once the product name is clicked
- Filtering takes time
- Feedback should remain long enough for the user to read it.
- Difficult to find the next page
- Difficult to execute most tasks in mobile comparison to the desktop version
- Difficult to find user information change page
- Filter does not work
- Search Icon not in appropriate position
- Sort does not work
- Adding items took a lot of time
- Buttons for add to cart and submit are too close
- Page crashes very often
- All categories expanded by default so difficult to click banner
- Clicking on the search icon doesn't work, only pressing enter works
- No option for filtered search from the beginning, option comes up after an item is searched
- Add to bag' was misleading
- Difficult to use slider. A manual input box should be used
- Use of gps or maps to set location
- When adding products to the wishlist, it took a decent amount of time for the products to appear in the wishlist
- Due to the recommendation bar of installing the app, I couldn't find the cart option, after removing the recommendation bar in browser I found the cart option.
- Color of the wishlist should be changed
- In the FAQ section, I did not find any information after clicking the shipping and return link and it redirected me to an empty page.
- I have to go to each individual product page to add a product. No input method to add a product from the search list.

All of the usability issues that users faced were easily mapped to the current set of heuristics that were created. There were some problems that were detected by multiple users while others were only detected by a single person. The frequency of the number of problems found for each specific heuristic can be seen given below:

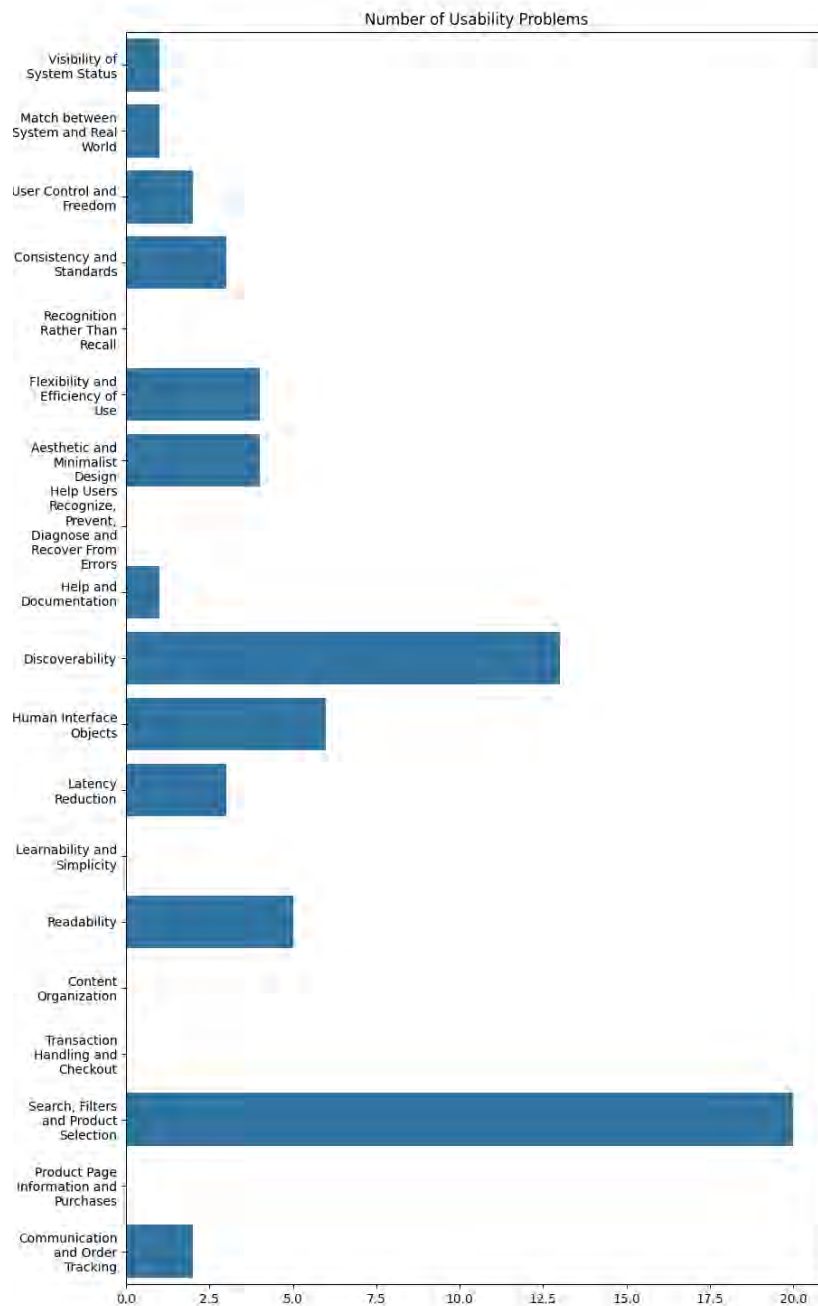


Figure 4.5: Usability Problems per heuristic from User testing

Users were able to find the greatest number of problems related to the heuristics search, filter and product selection, and discoverability. However, they were unable to find any usability issues that were related to the heuristics recognition rather than recall, help users recognize, prevent, diagnose and recover from errors, learnability and simplicity, content organization, transaction handling and checkout, product page information and purchases. However, it was brought to our attention that the sub-problem related to authentication should be integrated to one of the heuristics. In case of conflicting usability issues, the problem obtained through user testing was prioritized. One such case was that users stated having issues with functions that were present on desktop but not on mobile which went against the sub-heuristic of learnability and simplicity which stated that non-available functionalities should be hidden so this sub-heuristic was removed and similar functionality for both devices was added to user control and freedom. Lack of social authentication mechanism was also a new heuristic that was observed during user testing and so being a single issue was added to transaction handling and checkout to form social authentication, transaction handling and checkout.

## 4.5 Stage 7: Refinement Stage

Currently, our set of heuristics consists of 19 heuristics. In comparison, the most used set of heuristics, Nielsen’s heuristics, consists of 10 heuristics. According to Weinreich[7], people often read 28 percent of the words during a visit with 20 percent more likely and the percentage of words in a page read decreases with the increase in the number of words. Similarly, evaluators might be unwilling to use a list that is much larger than the normally used heuristic set. As a result, we tried to reduce the size of the set as much as possible without losing sufficient information. This process would also help in removing any duplicate sub-heuristics that might exist in the list. Moreover, the problems in the previous stage that required to be explicitly stated were added to the heuristics. Some of the heuristics were also renamed so that evaluators would find it easy to understand them. A table is provided consisting of the heuristics that were merged together for the heuristic set:

Table 4.4: Heuristic Refinement Process

| Initial Heuristic                                                    | Final Heuristic                                    |
|----------------------------------------------------------------------|----------------------------------------------------|
| Visibility of System Status                                          | Effective Use of Feedback                          |
| Match Between System and Real World + Recognition Rather Than Recall | Real-World Language and Memory Efficiency          |
| User Control and Freedom                                             | User Control and Freedom                           |
| Consistency and Standards + Latency Reduction                        | Consistent Design Standards and Latency Management |
| Flexibility and Efficiency of Use                                    | User Efficiency                                    |

|                                                                                                   |                                               |
|---------------------------------------------------------------------------------------------------|-----------------------------------------------|
| Aesthetic and Minimalist Design                                                                   | Minimalist and Elegant Design                 |
| Help Users Recognize, Prevent, Diagnose and Recover From Errors + Help and Documentation          | Help, Documentation and Error Handling        |
| Readability + Discoverability                                                                     | Readability and Discoverability               |
| Human Interface Objects                                                                           | UI Element Optimization                       |
| Learnability and Simplicity                                                                       | Learnability and Simplicity                   |
| Content Organization                                                                              | Content Organization                          |
| Social Authentication, Transaction Handling and Checkout + Product Page Information and Purchases | Seamless Authentication, Payment and Checkout |
| Search, Filters and Product Selection                                                             | Search, Filtering and Product Information     |
| Communication and Order Tracking                                                                  | Communication and Order Tracking              |

An explanation of the final set of heuristics is provided below based on Rusu's provided template:

## 1. Effective use of Feedback

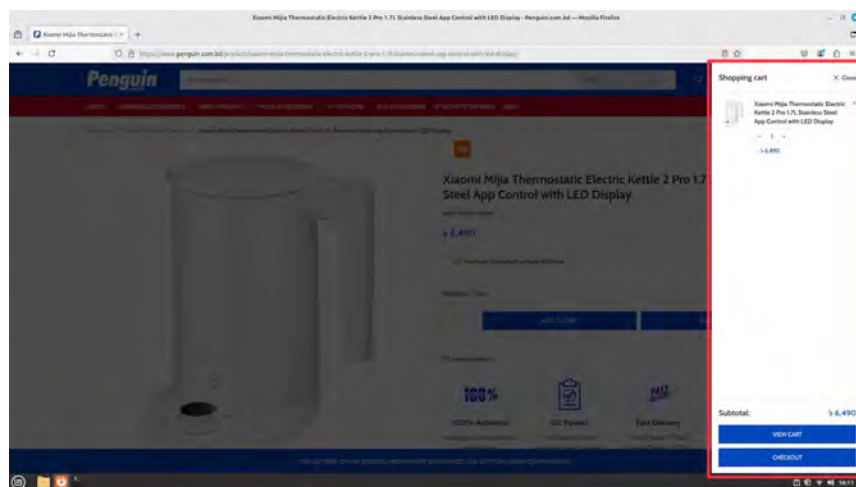


Figure 4.6: Immediate Feedback provided for item added to cart

ID: EUH1

Definition: Inform the user of what is going on through feedback in a suitable

amount of time.

Explanation: Users should be provided timely feedback for their actions as simply as possible with accuracy and remain long enough for them to read it. It should also use multi-modal feedback utilizing the device's hardware capabilities.

Example: Immediate Feedback provided for item added to cart

Benefits: Users can properly react to feedback and act accordingly.

Problems: The feedback may use a form of sense that the user might lack thereof such as use of sound for a deaf person would not be useful.

## 2. Real-World Language and Memory Efficiency

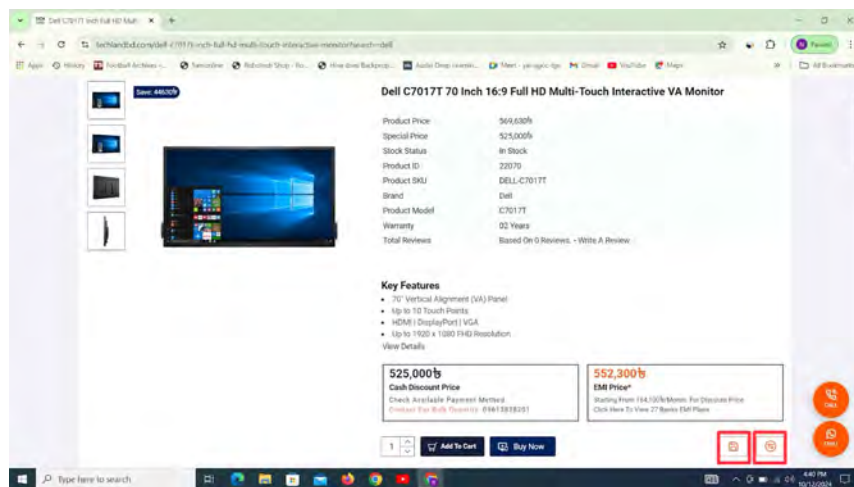


Figure 4.7: Difficult to understand what the save icon and the icon next to it means

ID: EUH2

Definition: Avoid the use of technical terms and use real world conventions while ensuring minimal cognitive load. Explanation: It should employ the use of words, phrases and concepts that they can relate to through elements that are present in their everyday life and culture. Users should be allowed to recognize information rather than recalling it. This can be done through the use of default values, dropdowns, filled in textfields or information provided through visible objects in the interface from one page to the other.

Example: Appropriate icons or buttons with text should be used to represent the add to wishlist and compare items instead of icons.

Benefits: Makes it easy for the users to use the system due to familiarity with it and low mental effort to work efficiently.

Problems: People have differing beliefs and culture and so real-world aspect may differ from person to person.

### 3. User Control and Freedom

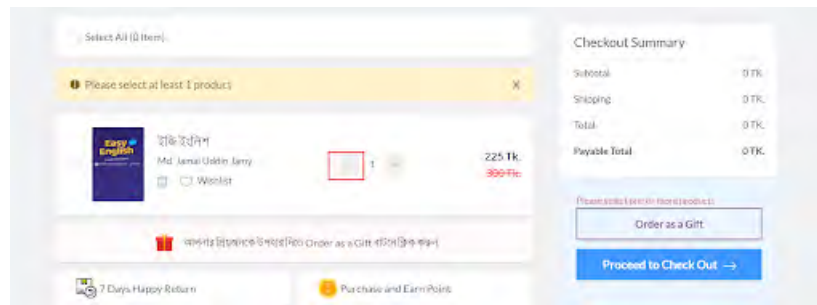


Figure 4.8: No way to remove items from cart

ID: EUH3

Definition: An appropriate balance of freedom and control should be utilized for the user.

Explanation: Provide actions that are only requested by the user while ensuring they can solve tasks based on their choices even if it is inefficient. Allow users multiple ways to get a task done as well as customizing it to fit their choices. Ensure that all devices have the same functionality along with special accessibility options for those with user needs. Use constraints only if the action is irreversible.

Example: Allow users an undo button to remove items from the checkout page or in the cart page right after they have been added.

Benefits: Users have a sense of ownership and will be more efficient making them more motivated to continue to use the system. Problems: Has conflicting correlations with user efficiency as well as error handling but it should be noted that this heuristic is contextually more user focused allowing user's to take their desired actions and have control over them.

### 4. Consistent Design Standards and Latency Management

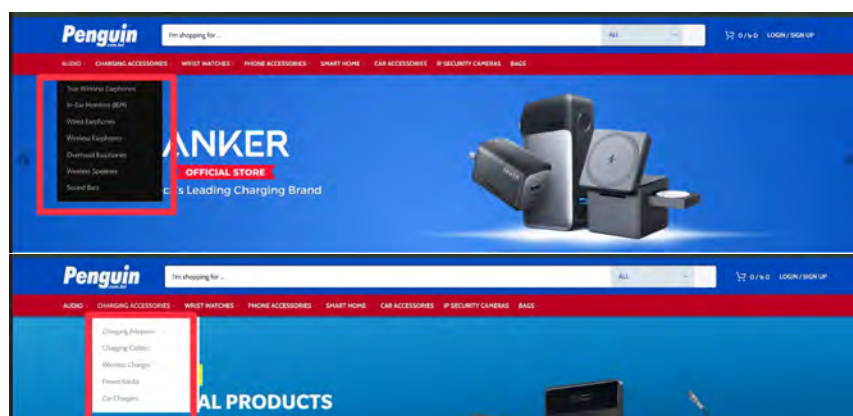


Figure 4.9: Differing color of dropdowns

ID: EUH4

Definition: Follow established conventions for similar E-commerce websites as

well as page to page consistency. Ensure that the user has optimized latency throughout the system. Explanation: Maintain consistent design patterns for various user groups and ensure objects with similar design have the same functionality. Standard conventions for shortcuts and gestures should not be changed unless necessary. Minimize latency by removing or reducing the quality of high quality animations and images or keep users engaged during this time.

Example: Dropdowns should have similar designs between them

Benefits: Less errors and easier for already experienced users to move to the system due to prior experience and familiarity. Users would also not leave due to delays of processing.

Problems: If the layout is an exact copy, people might not use it simply because there is nothing new to add. Moreover, it is a given that certain functions will take a long time as an efficient solution to a problem may not have yet been discovered.

## 5. User Efficiency

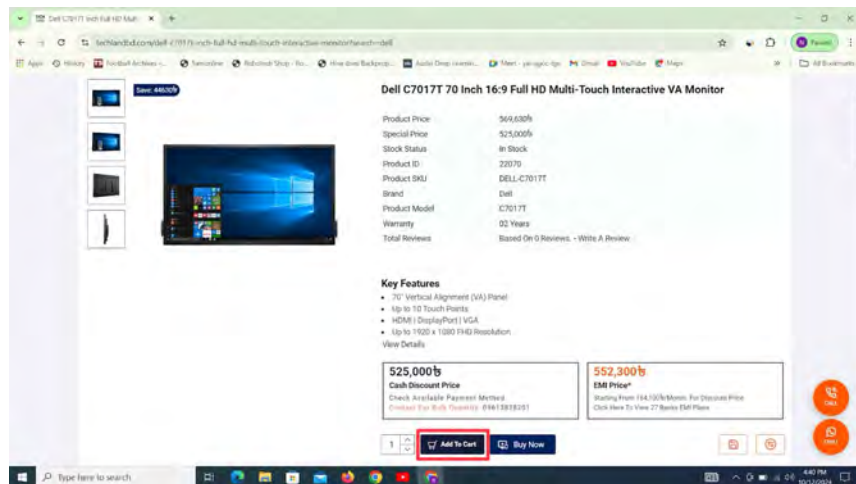


Figure 4.10: Add to cart located at very bottom requiring more user effort

ID: EUH5

Definition: Ensure that both novice and advanced users are productive when using the system.

Explanation: Keyboard shortcuts should be provided for experienced users while hiding them from novice users. Time to move and scroll to objects as well as the time taken to solve a task should be minimized. The number of screen transitions should be reduced by introducing screen overlays and modals. Maximize the use of selection methods over typing along with sticky navigation for easy access.

Example: Reduce time to move to necessary buttons such as the "Add to Cart" button.

Benefits: A more efficient system would mean that people could spend less time trying to solve a task and enhance user satisfaction.

Problems: No effective criterion has been decided on the time taken to do a task or the time to move or scroll to an object and so is dependant on the evaluator's opinion.

## 6. Minimalist and Elegant Design

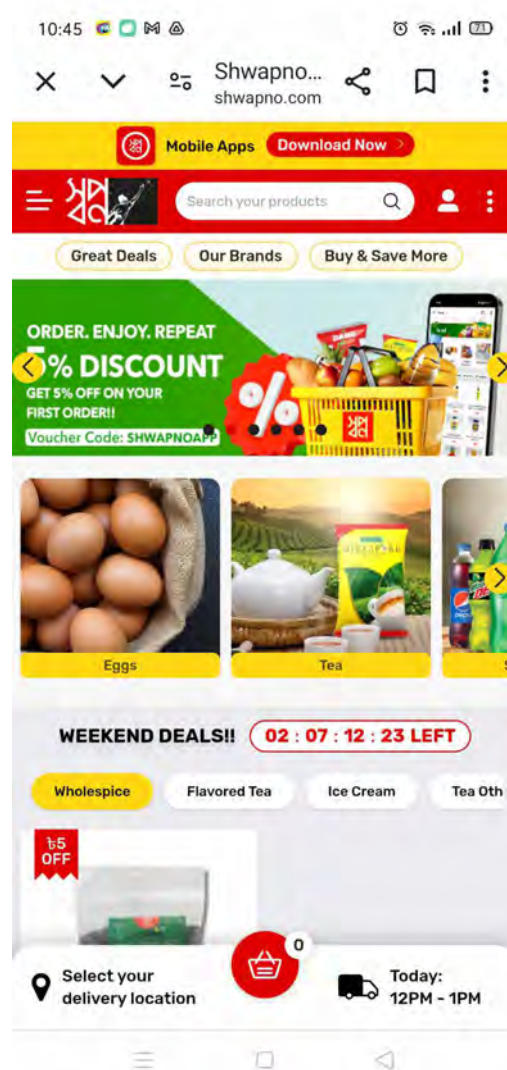


Figure 4.11: Too much information provided in a single page with repetition overwhelming the user

ID: EUH6

Definition: Attract user attention for all senses and minimize the use of irrelevant information.

Explanation: Remove unnecessary elements from the design and leverage the use of banners, sounds and animations to attract users. Ensure that the quality of the image or animation is appropriate for visual clarity while avoiding excessive or irrelevant information. Maintain an appropriate balance between aesthetics and functionality to attract users without overwhelming them.

Example: Page should provide only the necessary information needed with the rest kept at lower parts of the page.

Benefits: Uses fewer resources and fewer visual cues that may overwhelm the user.

Problems: Measurement for minimalism depends on evaluator and so some

pages might require a lot of information. Difficult to decide color cues as some users may be color blind.

## 7. Help, Documentation, and Error Handling



Figure 4.12: Products are closely grouped together which can lead to accidental clicks

ID: EUH7

Definition: The website should provide documentation for users if there are new features and provide users ways to prevent, diagnose and recover from errors.

Explanation: Ensure that the help and documentation are provided only when the user needs it and is concise along with the steps listed down. Error messages should be easy to understand and should be colored red. The system should save the user's work and provide helpful constraints and defaults to avoid errors. Provide undo and redo options as well as other useful shortcuts for correcting errors. Provide effective distance between interactive elements to avoid slips.

Example: Products should have sufficient distance between them to avoid accidental clicks

Benefits: Users would be less frustrated when faced with continuous issues since required steps can reduce user frustration.

Problems: Some functions require permanent changes and might often be impossible to recover from. Too many defaults and constraints that require constant changing may lead to user frustration.

## 8. Readability and Discoverability

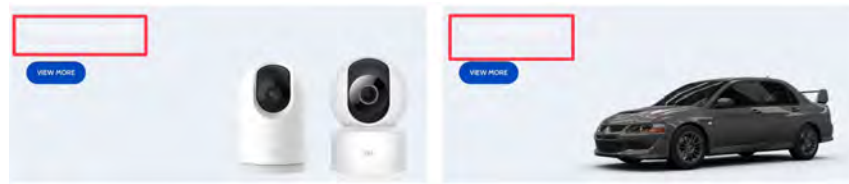


Figure 4.13: Title text for sections are too difficult to read

ID: EUH8

Definition: The website should make information easy to find and read.

Explanation: Ensure that text has high contrast with the background and important text is large enough to be read. Ensure there is sufficient space between words, lines and paragraphs. Design and position buttons, menus and the navigation bar such that they are easy to find while avoiding broken or missing links. Provide a site map for quick navigation. Provide specific shortcuts at the start and stop showing them when the user becomes familiar with it.

Example: Use a high-contrast color scheme with a large font for different categories of items.

Benefits: Users will not find it difficult to read text and discover crucial interactive objects for certain tasks so would have less frustration. Problems: Evaluators may try to increase the text size of all text to be readable and try to ensure that all necessary interactable objects are visible.

## 9. UI Element Optimization

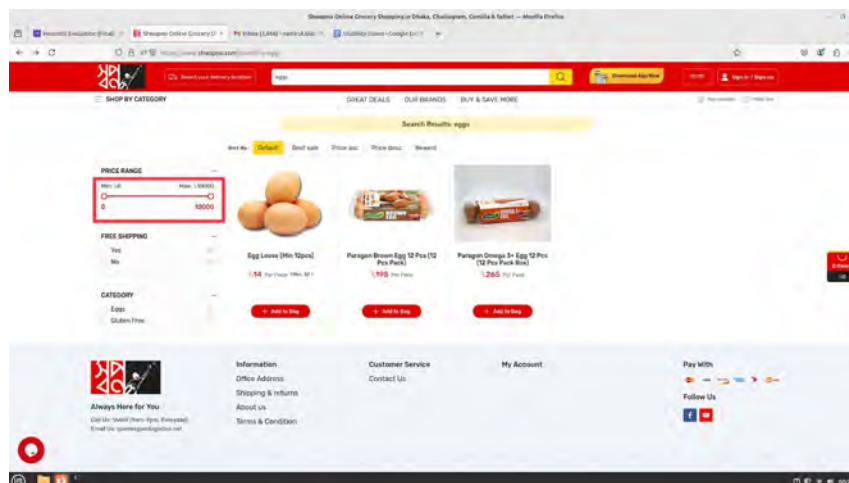


Figure 4.14: Difficult to use slider to set a specific value

ID: EUH9

Definition: The website should ensure optimized design, functionality and interaction of interactable user elements.

Explanation: Use larger objects for tasks users are more likely to perform and ensure they are easily perceived and manipulatable. Ensure that if there are

multiple ways to use them, all of them should work. Clearly distinguish their hit area and ensure they are understandable, consistent and user-friendly.

Example: Use manual text fields instead of sliders for selecting price range.

Benefits: Optimized UI elements will ensure that users will be able to efficiently do their tasks.

Problems: Evaluators may focus heavily on optimization of UI elements that are hardly used.

## 10. Learnability and Simplicity

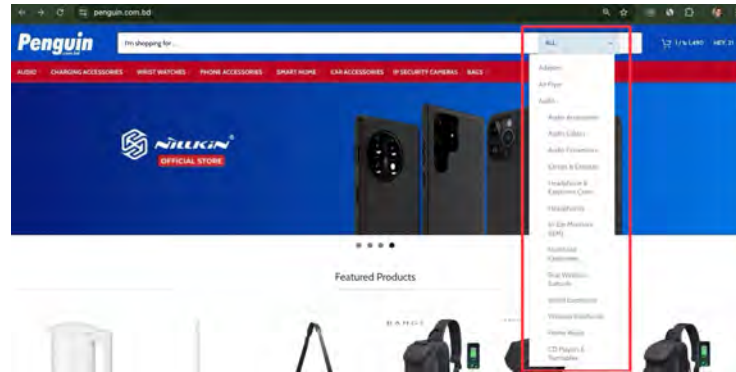


Figure 4.15: Difficulty to get used to dropdown located at the right of the text field

ID: EUH10

Definition: The website should be utilize an optimal balance between learning and ease of use.

Explanation: Ensure learnability and ease of use are appropriately balanced. Reduce the number of steps needed to complete a task. Minimize user workload and provide visual aids such as pictures and animation to ease the learning process. Ensure gestures and button placement are consistent with where users expect to find them. Provide clear navigation with accurate title for all pages.

Example: Ensure filters are placed at the same or similar locations as other E-commerce websites.

Benefits: New users would find it easy to use the system more effectively.

Problems: It is difficult to determine the learnability and the simplicity of the website as users would need to interact with it for sufficiently long periods of time.

## 11. Content Organization

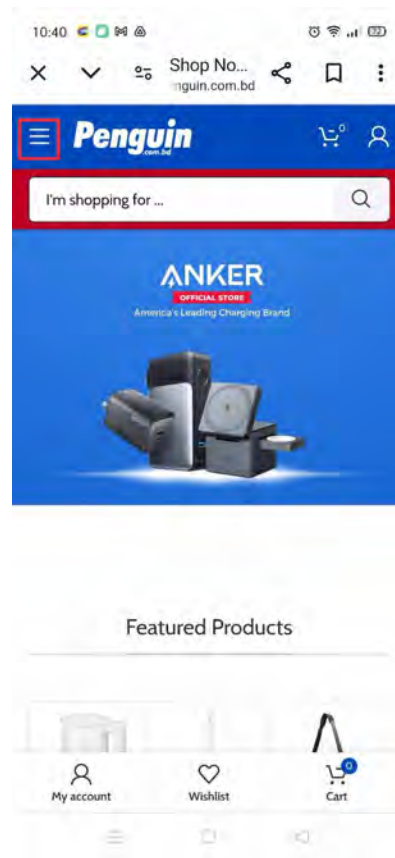


Figure 4.16: Provide Hamburger icons with sufficient distance between interactive objects for smaller screens

ID: EUH11

Definition: The website should be optimized to handle different screen sizes.

Explanation: Use menu or list selection for smaller screens but ensure that the number of menu options is few. Content should fit the screen and larger content should be displayed in multiple screens. Avoid opening of new tabs or windows on mobile devices and provide all significant images and titles on all important pages. Ensure that interactive elements have sufficient distance between them and are long enough to display common data with minimum typing.

Example: Use a collapsible menu on a mobile app to keep the screen uncluttered and allow users to navigate easily between sections.

Benefits: Users from devices of different sizes can enjoy using the application.

Problems: Evaluators may confuse it with consistent design standards and latency management. Consistent design standards will ensure that the system has consistent design in comparison to other e-commerce websites as well as internal consistency. Content organization on the other hand ensures that the content is organized in a way appropriate for devices of all size.

## 12. Seamless Authentication, Payment and Checkout ID: EUH12

The screenshot shows the Penguin.com checkout page. The top navigation bar includes links for HOME, CHANNEL ACCESSORIES, BEST WATCHES, PHONE ACCESSORIES, SMART HOME, CAR ACCESSORIES, IP SECURITY CAMERAS, and BAGS. The main content area is divided into three sections: Billing Details, Your Order, and Payment Information. The Billing Details section contains fields for Email address, First Name, Last Name, Street address, District, Town/City, and Postcode. The Your Order section displays a table with columns for PRODUCT and SUBTOTAL, showing a total of £1,550. The Payment Information section includes a red box highlighting the 'Pay with card' option and a 'PLACE ORDER' button at the bottom.

| PRODUCT                         | SUBTOTAL      |
|---------------------------------|---------------|
| 6.2" Hinge Smartphone (16GB) v1 | £1,490        |
| Warranty (2 Year)               |               |
| <b>Subtotal</b>                 | <b>£1,490</b> |
| <b>Shipping</b>                 | <b>£60</b>    |
| <b>Total</b>                    | <b>£1,550</b> |

Figure 4.17: Lack of multiple payment options

**Definition:** The website should ensure effective user creation and signing in processes and streamlined transaction process.

**Explanation:** Successful transactions should be completed in a timely manner with a purchase confirmation button. The website should provide guest checkout and social authentication options. Checkout information should provide complete and transparent purchase information along with payment and shipping options with an order summary confirmed through email. The checkout process should be divided into multiple logical steps along with a progress bar at the top.

**Example:** Provide both on cash delivery as well as mobile banking options for payment

**Problems:** Transaction is a complex process and evaluators might find it difficult to evaluate each of them.

### 13. Optimized Search, Filtering and Product Information

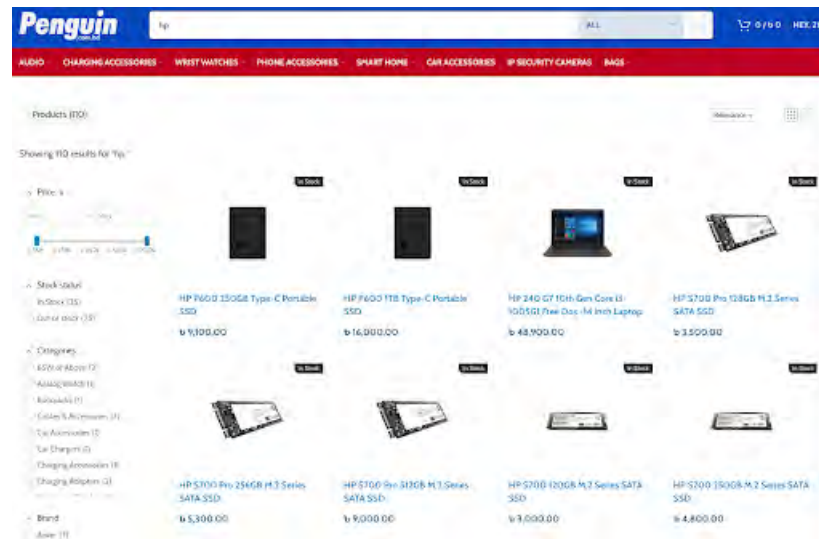


Figure 4.18: Irrelevant Search Results

ID: EUH13

Definition: The website should allow easy and efficient search for products users are looking for.

Explanation: The search box should be displayed at the top and ensure relevant results for the user. Out of stock items should have an estimated price and day of availability. Allow customers to rate, review, compare, modify, cancel and return products as well as allowing them to add it to the wishlist. Make it easy for users to add the product to the cart from the product selection page.

Example: Searching for printers should result in mostly printers.

Benefits: Users would be more satisfied as the core functions of the website works accurately raising user satisfaction.

Problems: Difficult to evaluate the types of filters that would be needed as different products would have different categories and would require extensive study based on user behaviour.

## 14. Communication and Order Tracking

The screenshot shows the Penguin website's checkout page. The 'Billing Details' section is highlighted with red boxes around the 'Street address', 'Country', 'Town / City', and 'Postcode' fields. The 'Payment Information' section shows 'Cash on delivery' selected. The 'Your Order' summary on the right lists the product '62 Panga Longline WGB MC x 1', the subtotal '£ 1,490', shipping '£ 100', and a total of '£ 1,590'.

| PRODUCT                      | SUBTOTAL       |
|------------------------------|----------------|
| 62 Panga Longline WGB MC x 1 | £ 1,490        |
| Shipping                     | £ 100          |
| <b>Total</b>                 | <b>£ 1,590</b> |

Figure 4.19: Manual inputs for location

ID: EUH14

Definition: Website should ensure users are able to communicate with sellers as well as selecting their location to track orders for purchases.

Explanation: Provide multiple contact options for customers in the form of emails, forms, phone to communicate with sellers and ensure they are easy to use. Offer customers a simple way to track orders along with date and time. Ensure that it is easy to add delivery locations specially through GPS.

Example: Add location detection through GPS instead of text-fields and provide contact information of the seller in contacts.

Benefits: Users would feel more secure knowing about the status of their purchase.

Problems: Evaluators may mistake this heuristic with Help, Documentation and Error Handling. Help, Documentation and Error handling focuses on communication with the support group of the website while Communication and Order Tracking focuses on communication with the person or group selling the product.

## 4.6 Stage 8: Evaluation Stage

For evaluating the heuristic, we have decided to adopt the user testing process along with the Method Adoption Model(MAM) developed by Paz et al[24]. The Method Perception Model was developed from the concepts of Methodological Pragmatism which is a theory for evaluating methodological knowledge, and the Technology Acceptance Model which uses a theory-based model to explain and predict whether a user would accept the form of technology that has been provided. Despite it may seem that the adoption of a form of technology may be due to how efficient and

how effective it is, its actual usage is actually a result of human perceptions and limitations. The factors that were taken into consideration in this model are given below:

- **Perceived Ease of Use(PEU):** The extent to which an evaluator thinks a specific usability heuristic is easy to use.
- **Perceived Usefulness(PU):** The extent to which an evaluator thinks a specific usability heuristic will achieve its goal.
- **Intention to Use(IU):** The extent to which an evaluator is likely to use the entire set of heuristics in the future for evaluating user interfaces.
- **Perceived Completeness(PC):** The extent to which an evaluator believes how much of all the usability problems the proposed set of heuristics covers for the given domain.

An evaluator will only use a method if they deem it to be easier than and more useful than the currently used method. The intention to use a method and how complete it is for a given domain is decided at the end of the heuristic evaluation stage and is judged on the entire set of heuristics rather than for each heuristic.

#### 4.6.1 Nielsen's Heuristic

For this study, we have decided to compare it with Nielsen's heuristics[1]. This is because Nielsen's heuristic is considered the industry standard and a comparison to it will further elaborate how effective our heuristic is in comparison to Nielsen's heuristics. An explanation of Nielsen's heuristics has been collected from the Nielsen Norman Group's website[54] and is provided below:

1. **Visibility of System Status:** Users should know what is happening in the system from time to time
2. **Match Between System and Real World:** Avoid using complicated terminologies that are difficult to understand. Make information as human readable as possible by ensuring it follows a simple and rational sequence.
3. **User Control and Freedom:** Users should be able to opt out of any action they have made mistakenly without going too deep into the process.
4. **Consistency and Standards:** Users should not be confused about similar terms phrased or portrayed differently. The system should follow already existing patterns for similar websites.
5. **Error Prevention:** Prevent users from making mistakes in the first place by removing cases where errors are most likely and asking for verification when taking actions.
6. **Recognition Rather than Recall:** Reduce information users have to remember by ensuring the user understands the model of the system with information repeated in each page.

7. **Flexibility and Efficiency of Use:** Shortcuts should be easy to find only for experts so that they can work faster while being invisible for beginners.
8. **Aesthetic and Minimalist Design:** Unnecessary information should not exist on interfaces as they would compete for the user's attention and make other elements less visible.
9. **Help Users Recognize, Diagnose, and Recover from Errors:** Error messages should be easy to understand and provide a way to solve the issue.
10. **Help and Documentation:** The system should be self-explanatory but may provide guiding mechanisms to ensure greater task success rate.

#### 4.6.2 Experimental Setup

This experiment was conducted with 24 participants who worked in the industry in a type of role which was involved with design. Out of these 24 people, 19 of them worked in the industry in the role of a software engineer with at least a part or the whole of their role focused on front-end development. Out of these 19, 2 were full stack software engineers and 1 was a trainee software engineer working on design and front-end. Among the rest of the 5 people, 2 worked on UX Design and front-end engineers, 1 was a product manager and the rest of the 2 were app developers. Among the evaluators, 5 had experience less than 1 year, 11 had an experience between 1 to 3 years, 5 had an experience between 3 to 5 years and 3 had experience of over 5 years.

Distribution of Experience among Evaluators

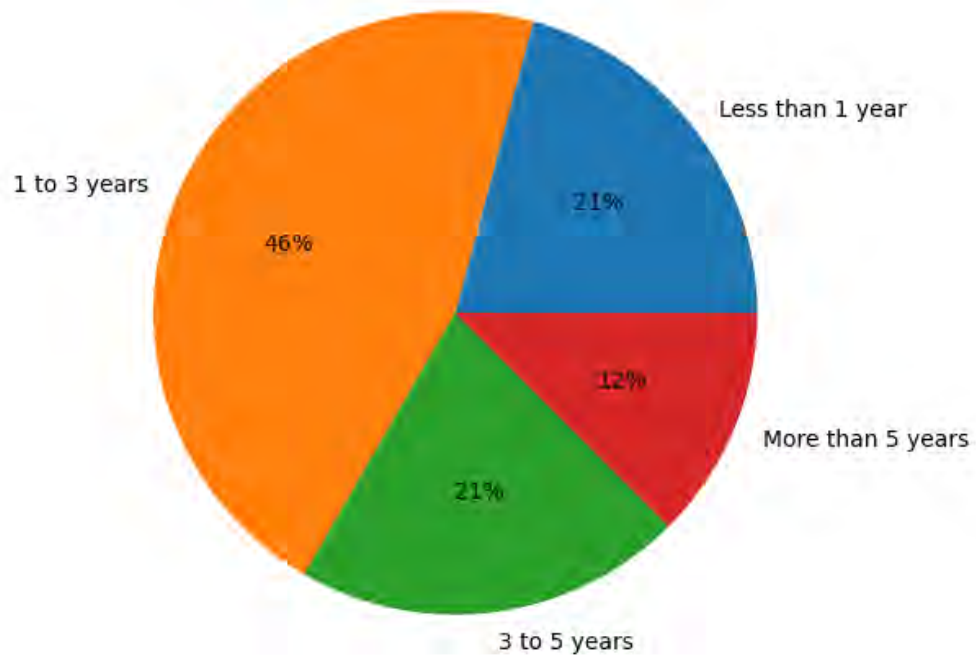


Figure 4.20: Usability Problems per heuristic from User testing

A form was provided for each user with the tasks that needed to be done with the tasks provided below:

1. Sign in to the website or Sign up
2. Search Products
3. Filter Products
4. Browse Product Categories
5. Read Product Reviews and Ratings
6. Add Products to Cart and Wishlist
7. Check Product Availability
8. Locate Return and Refund Policy
9. Locate and Use the FAQ Section
10. Reduce Quantity in Cart to less than zero

Separate docs were provided consisting of Nielsen’s heuristics and our heuristics for E-Commerce websites with the explanation in the form of bullet points for evaluators to perform heuristic evaluation with both the heuristics. The explanation for Nielsen’s heuristics were collected from the tips for each heuristic provided in Nielsen Norman Group’s website[54] while ours was formed from the explanation of each heuristic. The website chosen for the task was Penguin.com.bd, an E-commerce website focused on selling electronics and bags. The evaluators would have to use their email to fill up the form and were required to provide their profession and the years spent working on that profession. They would then, for each set of heuristics, find problems in the website based on the provided heuristics. The form was divided into 2 sections with one for each set of heuristic. Other than finding problems, evaluators would have to rate each heuristic both in Nielsen’s and our created set of heuristics in terms of their perceived usefulness and perceived ease of use. At the end of each section, they would have to rate the entire set in terms of intention to use and perceived completeness.

For user testing, we recruited 15 users and asked them to do the same tasks. Their form did not have any heuristics provided and their tasks were to provide a list of issues they found while completing the given tasks for both mobile devices and personal computers. These results were then used to compare how much more problems evaluators detected with our heuristic compared to Nielsen’s that were actually considered a problem according to users.

### 4.6.3 Results

Based on the form, users were tasked to find as many problems as possible based on both sets of heuristics. These problems would also be assigned with a severity score based on how serious the the evaluator would consider the problem. The severity of the scores was done in a 5-point Likert scale with the scores starting from 1 and ending at 5. The problems found by Nielsen’s and E-commerce heuristics is given below with their severity written next to them:

Table 4.5: Heuristic evaluation with Nielsen’s Heuristics

| Problems found by evaluator                         | Severity Rating |
|-----------------------------------------------------|-----------------|
| Overall design not very visually pleasing           | 4               |
| Product Zooming is odd                              | 4               |
| Difficult to return from cart to product page       | 3               |
| 7 easy steps to order in Product page really bad UX | 5               |
| Locate and Use the FAQ Section difficult to find    | 2               |

|                                                                                                                                      |   |
|--------------------------------------------------------------------------------------------------------------------------------------|---|
| No search icon in search bar                                                                                                         | 4 |
| Search button did not work                                                                                                           | 5 |
| Responsive problem footer section and so many space                                                                                  | 3 |
| Three log out options in one page<br><a href="https://www.penguin.com.bd/my-account/">https://www.penguin.com.bd/my-account/</a>     | 3 |
| Minimalist product display on products page (only title and price there, short description, ratings, etc missing)                    | 3 |
| Lack of immediate feedback on user actions (e.g., no hover effects on product images or visible "Add to Cart" and "Buy Now" buttons) | 3 |
| Coupon does not exist message displayed with green background, should be red.                                                        | 3 |
| Search bar and navbar went invisible in large screens all of a sudden                                                                | 5 |
| Inconsistent Naming - Login/Sign in                                                                                                  | 3 |
| Too many pictures with resolutions too large does not have any proportionality                                                       | 3 |
| Hyperlinks in the navbar does not route properly                                                                                     | 4 |
| The filter by price option was taking me the product pages instead                                                                   | 5 |
| Pages too cluttered                                                                                                                  | 5 |
| Any product in home page does not have any UI/animation change when hovered over it                                                  | 5 |
| Shipping partners in footer does not redirect                                                                                        | 3 |
| Poor labeling on navigation links                                                                                                    | 3 |
| Finding specific information from the help document                                                                                  | 3 |
| Customer review section cannot be found                                                                                              | 4 |
| Some navDrawer subItems return not found                                                                                             | 5 |
| Unclear prompts and instructions on item color selection                                                                             | 3 |
| Phone numbers do not link to call API                                                                                                | 4 |

|                                                                                                                                                              |   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| Message for add to card for stocked out items given with an alert instead of a message in the UI and the message does not say "Product not in stock" either. | 4 |
| Would be better to have Return and Refund policy page in the navbar as well, also the page is way too textual.                                               | 2 |
| Lack of "Reset filters" button                                                                                                                               | 4 |
| Stock status options are not there in product page                                                                                                           | 3 |
| color combination of button                                                                                                                                  | 3 |
| Sign up with social links text and image were broken                                                                                                         | 1 |
| Applying filter resets search                                                                                                                                | 5 |
| There is no upper bound to order and it is not responding to way too much of order                                                                           | 3 |
| does not stop scrolling, requires too much scrolling in product page                                                                                         | 5 |
| Lack of an "Undo" feature after actions like item deletion                                                                                                   | 4 |

Table 4.6: Heuristic evaluation with E-commerce Heuristics

| Problems found by evaluator                                 | Severity Rating |
|-------------------------------------------------------------|-----------------|
| Irrelevant search results                                   | 4               |
| Filter results not in any order by default                  | 3               |
| Latency issues in website, takes a lot of time to load      | 4               |
| Page does not resize properly                               | 5               |
| no tracking system of product                               | 4               |
| Without payment method and no phone verification            | 4               |
| Sliding carousel in home page mixes with background colours | 5               |
| Colours not very reader friendly                            | 5               |

|                                                                                                                                  |   |
|----------------------------------------------------------------------------------------------------------------------------------|---|
| Products cannot be added to cart directly have to go to details of each product to order                                         | 5 |
| Some images do not load properly on mobile devices                                                                               | 3 |
| After searching for something with a filter, some of the expected products were not shown                                        | 5 |
| Too many similar products with similar colors in featured products and other sections as well - difficult to distinguish         | 4 |
| No ratings displayed on product cards with need to visit each product to see ratings                                             | 5 |
| No sorting/filtering for customer ratings                                                                                        | 4 |
| Use of abbreviations like M/F for gender instead of clear labels                                                                 | 3 |
| No visual feedback during page loading                                                                                           | 3 |
| Small buttons for important functions, causing difficulty                                                                        | 4 |
| More focus on unwanted design elements rather than important ones                                                                | 4 |
| The filter was lackluster.                                                                                                       | 3 |
| Overall design not very visually pleasing                                                                                        | 4 |
| Product Zooming is odd                                                                                                           | 4 |
| Difficult to return from cart to product page                                                                                    | 3 |
| 7 easy steps to order in Product page really bad UX                                                                              | 5 |
| Locate and Use the FAQ Section difficult to find                                                                                 | 2 |
| No search icon in search bar                                                                                                     | 4 |
| Search button did not work                                                                                                       | 5 |
| Responsive problem footer section and so many space                                                                              | 3 |
| Three log out options in one page<br><a href="https://www.penguin.com.bd/my-account/">https://www.penguin.com.bd/my-account/</a> | 3 |
| Lack of information on products page                                                                                             | 3 |

|                                                                                                                                                              |   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| Lack of immediate feedback on user actions (e.g., no hover effects on product images or visible "Add to Cart" and "Buy Now" buttons)                         | 3 |
| Coupon does not exist message displayed with green background, should be red.                                                                                | 3 |
| Search bar and navbar went invisible in large screens all of a sudden                                                                                        | 5 |
| Inconsistent Naming - Login/Sign in                                                                                                                          | 3 |
| Too many pictures with resolutions too large does not have any proportionality                                                                               | 3 |
| Hyperlinks in the navbar do not route properly                                                                                                               | 4 |
| The filter by price option was taking me the product pages instead                                                                                           | 5 |
| Pages too cluttered                                                                                                                                          | 5 |
| Any product in home page does not have any UI/animation change when hovered over it                                                                          | 5 |
| Shipping partners in footer does not redirect                                                                                                                | 3 |
| Poor labeling on navigation links                                                                                                                            | 3 |
| Finding specific information from the help document                                                                                                          | 3 |
| Customer review section cannot be found                                                                                                                      | 4 |
| Some navDrawer subItems return not found                                                                                                                     | 5 |
| Unclear prompts and instructions on item color selection                                                                                                     | 3 |
| Phone numbers do not link to call API                                                                                                                        | 4 |
| Message for add to card for stocked out items given with an alert instead of a message in the UI and the message does not say "Product not in stock" either. | 4 |
| Would be better to have Return and Refund policy page in the navbar as well, also the page is way too textual.                                               | 2 |
| Lack of "Reset filters" button                                                                                                                               | 4 |
| Stock status options are not there in product page                                                                                                           | 3 |

|                                                                                              |   |
|----------------------------------------------------------------------------------------------|---|
| color combination of button                                                                  | 3 |
| Sign up with social links text and image were broken                                         | 1 |
| Applying filter resets search                                                                | 5 |
| Login requires username or email address whereas registration does not even ask for username | 4 |
| There is no upper bound to order and it is not responding to way too much of order           | 3 |
| Does not stop scrolling, requires too much scrolling in product page                         | 5 |
| Lack of an "Undo" feature after actions like item deletion                                   | 4 |

Nielsen's set of heuristics were successful in finding 36 problems related to user interface of the website that has been tested. On the other hand, our created E-commerce specific heuristics was able to find 56 usability issues which is significantly higher in comparison to that of Nielsen's. The number of problems for each severity scale for each heuristic are provided below:

Table 4.7: Number of problems found per severity for each heuristic set

| Severity Score | Nielsen's List | E-Commerce Heuristics |
|----------------|----------------|-----------------------|
| 1              | 1              | 1                     |
| 2              | 2              | 2                     |
| 3              | 15             | 20                    |
| 4              | 9              | 18                    |
| 5              | 9              | 15                    |
| Total          | 36             | 56                    |

However, this method of comparison has received a lot of criticism as of late. In comparison to user testing methods, heuristic evaluation methods generate false positives which might misrepresent user issues[12]. Moreover, the comparison done is heavily dependant on the website and so would be a poor comparison of both the heuristics. The total results were compared with actual user tests and the results

obtained were then compared with the problems evaluators found. The number of problems detected and the comparison is given below:

The problems detected from user testing are given below:

- No filter option using product ratings
- Search button did not give appropriate results
- I cannot sort them according to ratings if I search for a product. The categories for sorting are different then
- There are no reviews and I did not see any option to write reviews
- No error message comes up if I try to reduce item to less than zero in checkout page
- Some hyperlinks show error 404
- Some products not available (phone accessories; phone cases showed error 404)
- Website visually not pleasing
- cannot add product to cart from searched page
- ratings are also not shown on products card
- would be better if some sort of videos regarding the product are shown in product page
- Couldn't add some products to the cart.
- Websites a bit slow to interact with
- Could not read customer reviews
- The page should have showcased their payment partners at the bottom of the homepage and I was frustrated to see that the only option was cash on delivery during checkout. The site should have mentioned it beforehand that they were only accepting COD. Watching payment partners at the bottom of the page would have subconsciously made the page more reliable to me.
- While scrolling down, since my internet was slow the page froze while loading more products instead maybe a logo with some type of loading screen might have been better
- In the homepage or in the search results the product alignment looked very dull and not interesting because there were no additional colours surrounding the products.
- The discount percentage sign font size was too small and also boring due to the same font style.
- Should colour the headers in home page (Featured products, Audio accessories). -2

- Colourless product thumbnails.
- Add to Wishlist font size too small.
- Popping up deals on site opening (such as check out our hot deals or puja sales or techtober offers). I think it will make the customers more conscious and excited and allover make the site less dull.
- I saw sales on products which should have been showcased in the home page. Such as they should be popping up, promoting or should have been in different sub-sections.
- In the home page at the bottom there's the (gaming headphones, gaming mouse and gaming keyboard) section which I think should be at the top.
- In the discounted products the previous price is coloured white which should be changed to a different colour to grab the customers's attention.
- When I was writing my gmail for signing up, during typing, after every character I pressed the register button kept popping up over my keyboard for a very short time which was quiet annoying.
- When signing up they did not ask me for my display name and automatically used my gmail which I did not like and while signing up I was not asked my first or last name.
- During checkout the billing details should have on the top and after the submitting my address they should refresh to the next page to show my order details.
- The search is probably not completely optimized
- Design is too basic
- there seems to be a lot of information on the product pages instead of highlighting some important details.

Table 4.8: Number of problems found through user testing

| Nielsen's heuristics | E-commerce heuristics | User tests only |
|----------------------|-----------------------|-----------------|
| 7                    | 20                    | 11              |

However among the 11 problems, 3 can be resolved with Nielsen's heuristics where the users expected the headers and product thumbnails to be colored as well as no error messages for reducing cart items to less than 1 for products. 5 can be resolved with our E-commerce heuristics consisting of the previously overlooked 3 along with the appropriate billing location and options to read and write reviews. This may be because the heuristics are hard to understand or evaluators may have subjectively ignored them. Among the problems that were not detected many were connected to

pop-ups and some were connected to user opinions. However, two were connected personalized user recommendations and appropriate user naming. Nevertheless, our newly created heuristic set was able to find 13 more problems than that of Nielsen's that were directly connected to user issues. Some issues that were already found by evaluators may not be significant enough to be considered major issues by users which is not surprising as heuristic evaluation is also used to find a large number of usability problems that are not so severe[12]. It would seem that the evaluators considered problems to be more severe than the average user.

Therefore a more appropriate method should be utilised which would not be dependant on the website but judge the heuristics on multiple parameters instead of a single parameter[26]. In order to do so, we utilized Paz's Method Adoption Model which would be a more appropriate comparison for the heuristics. The table below gives the score, rounded to 2 decimal places, for perceived usefulness and perceived ease of use for each heuristic in Nielsen's list as well as the average score for all heuristics:

Table 4.9: Perceived Usefulness and Perceived Ease of Use for Nielsen's heuristic

| Heuristic                                              | PU          | PEU         |
|--------------------------------------------------------|-------------|-------------|
| Visibility of System Status                            | 4           | 4.08        |
| Match Between System and Real World                    | 4.21        | 4.08        |
| User Control and Freedom                               | 4.25        | 4.17        |
| Consistency and Standards                              | 4.17        | 4.17        |
| Error Prevention                                       | 4.25        | 3.83        |
| Recognition Rather Than Recall                         | 4.04        | 3.92        |
| Flexibility and Efficiency of Use                      | 3.83        | 3.88        |
| Aesthetic and Minimalist Design                        | 4.17        | 4.17        |
| Help Users Recognize, Diagnose and Recover From Errors | 4.04        | 3.96        |
| Help and Documentation                                 | 3.75        | 4.04        |
| <b>Average Score</b>                                   | <b>4.07</b> | <b>4.03</b> |

The following table provides the score, rounded to 2 decimal places, for perceived usefulness and perceived ease of use for each heuristic in our created heuristic set as well as the average score for the entire heuristic set:

Table 4.10: Perceived Usefulness and Perceived Ease of Use for E-commerce Heuristics

| Heuristic                                           | <b>PU</b>   | <b>PEU</b>  |
|-----------------------------------------------------|-------------|-------------|
| Effective Use of Feedback                           | 4.29        | 4.13        |
| Real-World Language and Memory Efficiency           | 4.46        | 4.04        |
| User Control and Freedom                            | 4.33        | 4.25        |
| Consistent Design Standards, and Latency Management | 4.13        | 4.08        |
| User Efficiency                                     | 4.13        | 4.08        |
| Minimalist and Elegant Design                       | 4.08        | 4.04        |
| Help, Documentation, and Error Handling             | 4.04        | 4.13        |
| Readability and Discoverability                     | 4.29        | 4.29        |
| UI Element Optimization                             | 4.21        | 4.13        |
| Learnability and Simplicity                         | 4.33        | 4.21        |
| Content Organization                                | 4.21        | 4.21        |
| Seamless Authentication, Payment and Checkout       | 4.38        | 4.13        |
| Optimized Search, Filtering and Product Information | 4.38        | 4.38        |
| Communication and Order Tracking                    | 4.38        | 4.17        |
| <b>Average Score</b>                                | <b>4.26</b> | <b>4.16</b> |

A comparison is then done between the two sets of heuristics. Since the heuristics are not exactly same and have different number of heuristics, we decided to take the average for the perceived usefulness and perceived ease of use for the two sets of heuristics while the perceived completeness and intention to use are averaged for all users. This result is summarized on the table below:

Table 4.11: Comparison of Heuristics Using Method Adoption Model

| <b>Method Adoption Model Factors</b> | <b>Nielsen's List</b> | <b>E-commerce heuristics</b> |
|--------------------------------------|-----------------------|------------------------------|
| <b>Perceived Usefulness(PU)</b>      | 4.07                  | 4.26                         |
| <b>Perceived Ease of Use(PEU)</b>    | 4.03                  | 4.16                         |
| <b>Intention to Use(IU)</b>          | 3.71                  | 4.42                         |
| <b>Perceived Completeness(PC)</b>    | 3.5                   | 4.25                         |

Our newly created heuristics have a score above 4 for all factors of the Method Adoption Model. This score would mean that our heuristics were well received by the evaluators and the average feedback is overall positive. These results show that evaluators deemed them useful and easy to use as well as willing to use them for the future as they deemed it to be cover a good portion of usability issues for E-commerce websites.

Our current set of heuristics show an improved result over that of Nielsen's for all 4 factors that were taken into consideration. For perceived usefulness and perceived ease of use, we see that our heuristics have scored higher but the result, however, is not remarkable, since the score is just slightly higher. On the other hand, the scores for intention to use and perceived completeness shows a significant increase in our heuristics compared to that of Nielsen's. This shows that despite the slightly larger size, people were more willing to use our created heuristics in the future for evaluating E-commerce websites. Similarly, evaluators believe that our created heuristics are more complete than Nielsen's in the sense that they seem to cover more usability problems than that of Nielsen's developed heuristics.

# Chapter 5

## Conclusion

Usability of a website is a key factor in the usage of a website as it not only attracts new users but is also crucial in retaining them. In this paper we have constructed a set of usability heuristics that could be used to test the usability of e-commerce websites on both personal computers and mobile devices. No current method exists for developing heuristics for multiple domains so Rusu's methodology had to be modified with extra stages to develop a new methodology which was used to develop new heuristics. Overall, our new set of heuristics seemed to be perform better than Nielsen's heuristics according to the Method Adoption Model. However, this is not without its limitations. Not all people were willing to make purchases on the website and so the problems regarding transactions are few. Secondly, our validation has been centred around the usage of Bangladeshi E-commerce websites for personal computers and mobile devices which limits the generalizability of our heuristics to other regions and platforms. Finally, since data was collected using the data collection method from Systematic Literature Review, our data collection method would inherit its problem of missing certain studies that may have been important for the development of these heuristics. Nevertheless, we tried to limit this issue through user testing for issues.

In the future, we hope to extend the usability of E-commerce websites on other devices as well as adopt new features that use artificial intelligence such as recommendations and chatbots. We hope to generalize our heuristics for all types of E-commerce websites taking into account different regions and people with disabilities. Finally, we hope to apply other statistical methods to evaluate how effectively the heuristics identify usability issues by comparing it with other heuristics across other e-commerce platforms.

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