Universidade Estadual de Campinas
Instituto de Computação

INSTITUTO DE COMPUTAÇÃO

Vanessa Regina Margareth Lima Maike

Investigating Natural User Interfaces (NUIs) – Technologies and Interaction in the Context of Accessibility

Investigando Natural User Interfaces (NUIs) – Tecnologias e Interação em Contexto de Acessibilidade

CAMPINAS
2018

Vanessa Regina Margareth Lima Maike

Investigating Natural User Interfaces (NUIs) – Technologies and Interaction in the Context of Accessibility

Investigando Natural User Interfaces (NUIs) – Tecnologias e Interação em Contexto de Acessibilidade

Tese apresentada ao Instituto de Computação da Universidade Estadual de Campinas como parte dos requisitos para a obtenção do título de Doutora em Ciência da Computação.

Dissertation presented to the Institute of Computing of the University of Campinas in partial fulfillment of the requirements for the degree of Doctor in Computer Science.

Supervisor/Orientadora: Profa. Dra. Maria Cecília Calani Baranauskas

Este exemplar corresponde à versão final da Tese defendida por Vanessa Regina Margareth Lima Maike e orientada pela Profa. Dra. Maria Cecília Calani Baranauskas.

CAMPINAS
2018

Agência(s) de fomento e nº(s) de processo(s): CNPq, 160911/2015-0; CAPES

Ficha catalográfica
Universidade Estadual de Campinas
Biblioteca do Instituto de Matemática, Estatística e Computação Científica
Márcia Pillon D'Aloia - CRB 8/5180

M281i Maike, Vanessa Regina Margareth Lima, 1985-
Investigating Natural User Interfaces (NUIs) - technologies and interaction in the context of accessibility / Vanessa Regina Margareth Lima Maike. – Campinas, SP : [s.n.], 2018.

Orientador: Maria Cecília Calani Baranauskas.
Tese (doutorado) – Universidade Estadual de Campinas, Instituto de Computação.

1. Interação humano-máquina. 2. Acessibilidade. 3. Design universal. 4. Computação ubíqua. 5. Interfaces de usuário (Sistema de computador). I. Baranauskas, Maria Cecília Calani, 1954-. II. Universidade Estadual de Campinas. Instituto de Computação. III. Título.

Informações para Biblioteca Digital

Título em outro idioma: Investigando Natural User Interfaces (NUIs) - tecnologias e interação em contexto de acessibilidade
Palavras-chave em inglês:
Human-machine interaction
Accessibility
Universal design
Ubiquitous computing
User interfaces (Computer systems)
Área de concentração: Ciência da Computação
Titulação: Doutora em Ciência da Computação
Banca examinadora:
Maria Cecília Calani Baranauskas [Orientador]
Luciana Aparecida Martinez Zaina
Leonardo Cunha de Miranda
André Santanché
Marcos Augusto Francisco Borges
Data de defesa: 25-09-2018
Programa de Pós-Graduação: Ciência da Computação

Universidade Estadual de Campinas
Instituto de Computação

Vanessa Regina Margareth Lima Maike

Investigating Natural User Interfaces (NUIs) – Technologies and Interaction in the Context of Accessibility

Investigando Natural User Interfaces (NUIs) – Tecnologias e Interação em Contexto de Acessibilidade

Banca Examinadora:

- Profa. Dra. Maria Cecília Calani Baranauskas (Presidente)
  IC/UNICAMP
- Profa. Dra. Luciana Aparecida Martinez Zaina
  CCGT/UFSCar-Sorocaba
- Prof. Dr. Leonardo Cunha de Miranda
  DIMAp/UFRN
- Prof. Dr. André Santanché
  IC/UNICAMP
- Prof. Dr. Marcos Augusto Francisco Borges
  FT/UNICAMP

A ata da defesa, assinada pelos membros da Comissão Examinadora, consta no SIGA/Sistema de Fluxo de Dissertação/Tese e na Secretaria do Programa da Unidade.

Campinas, 25 de setembro de 2018

In order to be
irreplaceable,
one must always be
different.
(Coco Chanel)

Agradecimentos

O desenvolvimento desta tese configurou um trabalho árduo, intenso e recompensador. Pude mergulhar em ideias desafiadoras e brincar com vários dispositivos e tecnologias – sim, brincar! Apesar de difícil, foi divertido. Tenho orgulho das amizades que construí durante esses mais de 5 anos, e do legado que esta tese significa.

Portanto, em primeiro lugar, gostaria de agradecer aos meus pais, Sonia e Valter, pelo apoio incondicional. Vocês são a minha base e não há palavras para expressar a minha gratidão.

Um agradecimento especial também à minha orientadora, Profa. Cecília Baranauskas. Certamente é um privilégio ser sua aluna, e é impressionante o quanto você sempre tem a ensinar.

Agradeço a todos os colegas do grupo de pesquisa InterHAD com quem discuti ideias, realizei ensaios e tomei cervejas. Seu apoio e parceria contribuíram muito para o desenvolvimento desta tese. Um agradecimento especial àqueles com quem tive co-autoria; certamente, foi uma valiosa oportunidade de aprendizado.

Deixo um agradecimento a todos com quem convivi nesses anos, dentro e fora do Instituto de Computação (IC) da UNICAMP. Obrigada aos membros do LIS pela amizade, aos funcionários e professores do IC pelo apoio, e aos colegas de treino do judô e do CONDS pela parceria em manter a saúde física e mental.

Por fim, agradeço aos órgaos de fomento: à Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), processo #01-P-04554/2013, ao Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), processo #160911/2015-0, e à Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), processo #2015/16528-0, relativo ao projeto temático "*Sistemas Sócio-Enativos: Investigando Novas Dimensões no Design da Interação Mediada por Tecnologias de Informação e Comunicação*".

Resumo

Natural User Interfaces (NUIs) representam um novo paradigma de interação, com a promessa de ser mais intuitivo e fácil de usar do que seu antecessor, que utiliza mouse e teclado. Em um contexto no qual as tecnologias estão cada vez mais invisíveis e pervasivas, não só a quantidade mas também a diversidade de pessoas que participam deste contexto é crescente. Nesse caso, é preciso estudar como esse novo paradigma de interação de fato consegue ser acessível a todas as pessoas que podem utilizá-lo no dia-a-dia. Ademais, é preciso também caracterizar o paradigma em si, para entender o que o torna, de fato, natural. Portanto, nesta tese apresentamos o caminho que percorremos em busca dessas duas respostas: como caracterizar NUIs, no atual contexto tecnológico, e como tornar NUIs acessíveis para todos. Para tanto, primeiro apresentamos uma revisão sistemática de literatura com o estado da arte. Depois, mostramos um conjunto de heurísticas para o design e a avaliação de NUIs, que foram aplicadas em estudos de caso práticos. Em seguida, estruturamos as ideias desta pesquisa dentro dos artefatos da Semiótica Organizacional, e obtivemos esclarecimentos sobre como fazer o design de NUIs com Acessibilidade, seja por meio de Design Universal, seja para propor Tecnologias Assistivas. Depois, apresentamos três estudos de caso com sistemas NUI cujo design foi feito por nós. A partir desses estudos de caso, expandimos nosso referencial teórico e conseguimos, por fim, encontrar três elementos que resumem a nossa caracterização de NUI: diferenças, affordances e enação.

Abstract

Natural User Interfaces (NUIs) represent a new interaction paradigm, with the promise of being more intuitive and easy to use than its predecessor, that utilizes mouse and keyboard. In a context where technology is becoming each time more invisible and pervasive, not only the amount but also the diversity of people who participate in this context is increasing. In this case, it must be studied how this new interaction paradigm can, in fact, be accessible to all the people who may use it on their daily routine. Furthermore, it is also necessary to characterize the paradigm itself, to understand what makes it, in fact, natural. Therefore, in this thesis we present the path we took in search of these two answers: how to characterize NUIs in the current technological context, and how to make NUIs accessible to all. To do so, first we present a systematic literature review with the state of the art. Then, we show a set of heuristics for the design and evaluation of NUIs, which were applied in practical study cases. Afterwards, we structure the ideas of this research into the Organizational Semiotics artifacts, and we obtain insights into how to design NUIs with Accessibility, be it through Universal Design, be it to propose Assistive Technologies. Then, we present three case studies with NUI systems which we designed. From these case studies, we expanded our theoretical references were able to, finally, find three elements that sum up our characterization of NUI: differences, affordances and enaction.

List of Figures

1.1 Process adopted throughout the thesis. 20
1.2 The thesis process within the chapters. 24

2.1 Workflow of the study selection process. 30
2.2 Distribution of publication years of the selected papers. 31
2.3 Venn diagram of how many papers employed each of the Accessibility terms. 32
2.4 Types of work, categorized based on their goals, methods and contributions. 33
2.5 Categories of audiences identified in the selected papers. 33
2.6 Contexts of use identified in the selected papers. 35
2.7 Devices, hardware and other technologies identified in the selected papers. 35
2.8 Word cloud generated from the text excerpts that used the term Natural User Interface(s). 36
2.9 Word cloud generated from the text excerpts that used the terms from the accessibility context. 37
2.10 Word cloud made from the selected papers' abstracts. 38
2.11 Word cloud made from the selected papers' keywords. 39
2.12 Word cloud made from the selected papers' titles. 40

3.1 Specialists' evaluations in Experiments 1 (bottom row) and 2 (first five rows) 49
3.2 To the left, the original set of heuristics and, to the right, the new set of heuristics 50

4.1 Requirements represented in the Semiotic Framework (SF). 62

5.1 The high-level system architecture. 66
5.2 Example of our smart supermarket gondola. 67

6.1 Close-up of the game board while a person is playing our memory game. . 89

7.1 Neurosky's eSense scale for both Mediation and Attention levels, based on developer documentation. 104
7.2 The minimalist interface of our quiz, showing a relaxing image. 105

A.1 Stakeholders Identification Diagram (SID) 134
A.2 Evaluation Frame (EF) 134
A.3 Semiotic Framework (SF) 135

E.1 ACM Author Rights: `https://authors.acm.org/main.html` 172

List of Tables

3.1 Tested System and Participants of each experiment. 46

5.1 Execution times (in seconds) in the first workshop. 70
5.2 Execution times (in seconds) for Groups A-D. 71
5.3 Levels of Valence from the SAM questionnaire. 72
5.4 Levels of Arousal from the SAM questionnaire. 73
5.5 Levels of Dominance from the SAM questionnaire. 73
5.6 Amount of times users executed the main tasks in the first workshop. . . . 74
5.7 Amount of times users accessed product information. 75
5.8 Amount of times users accessed comments about products. 76
5.9 Amount of times users accessed comments about products. 76
5.10 Amount of times users heard the shopping list. 77

6.1 Results from the Self-Assessment Manikin. 92
6.2 How each group worked with players' perception and differences. 93

7.1 Questions from the quiz, with their corresponding answer, difficulty and set. 106
7.2 Average time (T) and levels of Attention (AT) and Meditation (MD) for each participant in the different types of images and question difficulties. . 108

Lista de Abreviações e Siglas

ADHD	Attention Deficit Hyperactivity Disorder
AI	Artificial Intelligence
ANOVA	ANalysis Of VAriance
ASSETS	Conference on Computers and Accessibility
AT	Assistive Technology
BCI	Brain-Computer Interface
CHIPLAY	Symposium on Computer-Human Interaction in Play
DIS	Conference on Designing Interactive Systems
EC	Embodied Cognition
EEG	Electroencephalography
EF	Evaluation Frame
EVA	Ethylene-Vinyl Acetate
GB	Gigabyte
GFR	Gear Face Recognition
GUI	Graphical User Interface
HCI	Human-Computer Interaction
HCII	International Conference on Human-Computer Interaction
ICISO	International Conference on Informatics and Semiotics in Organisations
ICT	Information and Communication Technology
IHC	Brazilian Symposium on Human Factors in Computing Systems
IoT	Internet of Things
MAP	Mean Amplitude Power
MEASUR	Methods for Eliciting, Analyzing and Specifying User's Requirements
MHz	Megahertz

NFC	Near Field Communication
NUI	Natural User Interface
OS	Organizational Semiotics
PD	Participatory Design
PoP	Publish or Perish
RAM	Random Access Memory
RFID	Radio-Frequency IDentification
RGB	Red-Green-Blue
SAM	Self-Assessment Manikin
SBGames	Brazilian Symposium on Computer Games and Digital Entertainment
SF	Semiotic Framework
SID	Stakeholders Identification Diagram
TEI	Conference on Tangible, Embedded and Embodied Interactions
TUI	Tangible User Interface
$U-NEXT$	Universal Navigation Exploration and eXchange with Things
UAIS	Universal Access in the Information Society
UD	Universal Design
UNICAMP	University of Campinas
USB	Universal Serial Bus
WoT	Web of Things

Contents

1 Introduction **16**
1.0.1 Objectives . . . 18
1.0.2 Research Method . . . 19
1.0.3 Thesis Organization . . . 20

2 Natural User Interfaces in the Context of Accessibility: A Systematic Review **25**
2.1 Introduction . . . 25
2.1.1 Rationale . . . 26
2.1.2 Objectives . . . 26
2.2 Method . . . 26
2.2.1 Eligibility Criteria . . . 27
2.2.2 Information Sources and Search . . . 27
2.2.3 Study Selection . . . 28
2.2.4 Data Collection Process . . . 28
2.2.5 Data Items . . . 28
2.2.6 Summary Measures . . . 29
2.2.7 Synthesis of Results . . . 29
2.3 Results . . . 29
2.3.1 Study Selection . . . 30
2.3.2 Synthesis of Results . . . 30
2.4 Discussion . . . 41
2.5 Conclusion . . . 42

3 Heuristics for NUI Revisited and Put into Practice **44**
3.1 Introduction . . . 44
3.2 The Heuristics in Practice . . . 45
3.3 The NUI Heuristics Revisited . . . 48
3.3.1 Change Criteria . . . 48
3.3.2 Before and After . . . 49
3.3.3 The Heuristics in Detail . . . 51
3.4 Conclusions . . . 54

4 Designing Natural User Interfaces Scenarios for All and for Some: an Analysis Informed by Organizational Semiotics Artifacts **55**
4.1 Introduction . . . 55
4.2 Theoretical Basis . . . 56
4.3 The Instantiated Artifacts and Case Studies . . . 57
4.3.1 Microsoft® Kinect and the Visually Impaired . . . 58

4.3.2 Samsung® Galaxy Gear and the Visually Impaired 59
4.3.3 Web of Things in the Supermarket 60
4.4 Results and Discussion 61
4.5 Conclusions and Future Work 63

5 A Smart Supermarket must be for All: a Case Study Including the Visually Impaired 64
5.1 Introduction 64
5.2 The U-Next System Architecture 65
5.3 Case Study 67
5.3.1 Scenario and Participants 67
5.3.2 First Workshop: Pilot Experiment 68
5.3.3 Second Workshop: Formal Experiment 68
5.3.4 Method 68
5.4 Results and Discussion 69
5.4.1 Execution Time 70
5.4.2 Satisfaction, Motivation and Control 72
5.4.3 Amount of Tasks Execution 74
5.4.4 Qualitative Feedback 77
5.5 Conclusion 80

6 A Memory Game for All: Differences and Perception as a Design Strategy 82
6.1 Introduction 82
6.2 Related Work 83
6.2.1 Search Strategy 83
6.2.2 Memory Game 84
6.2.3 Health 85
6.2.4 Learning 86
6.2.5 Adaptation from Visual Information 87
6.3 Case Study 88
6.3.1 Game Design 88
6.3.2 Participants and Method 89
6.3.3 Results 90
6.4 Discussion 93
6.4.1 Differences 93
6.4.2 Perception 95
6.4.3 Difference and Perception as a Design Strategy 96
6.5 Conclusion 97

7 An Enactive Perspective on Emotion: a Case Study on Monitoring Brainwaves 98
7.1 Introduction 98
7.2 Emotion Captured through EEG Devices 99
7.3 Emotion through the Lens of Enactive Approaches 101
7.4 Case Study 103
7.4.1 Technical Setup 104
7.4.2 Design of the Experiment 106
7.4.3 Quantitative Results 108

7.4.4 Qualitative Results . . . 109
7.5 Discussion Towards an Enactive Scenario . . . 110
7.6 Conclusion . . . 112

8 Conclusion **113**

Bibliography **119**

A Organizational Semiotics Artifacts Filled In **133**

B Original NUI Heuristics **136**

C Forms for Using the NUI Heuristics (English and Portuguese) **138**

D Ethics Committee Documentation **149**

E Authorizations for Using Published Articles **168**

Chapter 1

Introduction

When unveiling the Microsoft Kinect, Steve Ballmer [12] said: "*I believe we will look back on 2010 as the year we expanded beyond the mouse and keyboard and started incorporating more natural forms of interaction such as touch, speech, gestures, handwriting, and vision – what computer scientists call the 'NUI' or natural user interface.*"

When defining NUI, however, Wigdor & Wixon [137] turn the focus away from specific technologies or forms of interaction: "*The term natural is a powerful one, in that it quickly evokes a range of imagery in those who hear it. The first, and most important, thing to understand is that we use it to describe a property that is actually external to the product itself. The natural element of a natural user interface is not about the interface at all. Quite the opposite. We see natural as referring to the way users interact with and feel about the product, or more precisely, what they do and how they feel while they are using it.*"

In the same year, Norman [98] took the quote from Ballmer and pondered upon how natural NUIs really are: "*Control of our systems through interactions that bypass the conventional mechanical switches, keyboards, and mice is a welcome addition to our arsenal. Whether it is speech, gesture, or the tapping of the body's electrical signals for ´thought control', all have great potential for enhancing our interactions, especially where the traditional methods are inappropriate or inconvenient. But they are not a panacea. They come with new problems, new challenges, and the potential for massive mistakes and confusion even as they also come with great virtue and potential.*" In the end, Norman concluded that NUIs are not natural (but will be useful), and he constructs his arguments using gestural interfaces as an example. The author explains how this new form of interaction would have to establish standards and adopt development lessons from its predecessor, the Graphical User Interfaces (GUIs).

Norman also mentions how a same gesture can have different meanings in different cultures. Malizia & Bellucci [83] further analyze this aspect: "*Imposing a standard, especially when it is about cultural topics (such as gestures), can easily fail due to natural differences among human beings: for example, think about the Esperanto language, which failed to be widely adopted because of its artificiality. Technology is an interesting aspect to consider because, even if a gesture is not the most natural one, it can become natural due to the widespread use of technology adopting it. But, again, when it comes to cultural issues this can be quite difficult, as in the case of the English language, which is imposed as* *the de facto standard. Nevertheless, non-native speakers will always encounter difficulties in being proficient.*" The authors propose that participatory practices could be a possible solution to find a vocabulary of gestures with the highest consensus.

This solution hints to what O'Hara et al. [100] call a "positivist" perspective on naturalness, which focuses on ergonomic aspects of interaction, like learnability, ease of use and intuitiveness: "*Such representations and models can ultimately form the basis for defining interfaces to the digital world that will, broadly speaking, mimic their 'real-world' counterparts. The naturalness of these interactions is something that is taken as purely a problem of representation, ensuring that they are correctly represented in the interaction mechanism itself. In this sense, natural interactions are something detached from the social context in which they might be deployed; they are not constituted by the context, but brought to it.*"

In contrast with this perspective, O'Hara et al. [100] present another line of inquiry, called "embodied interaction", based on a situated and phenomenological approach: "*there are a broader set of concerns, beyond the objective characterization of the body, that relate to the lived bodily experiences of the embodied actor interacting with these systems. Naturalness, here, is an occasioned property of action that social actors actively manage and produce together in situ through their interaction with each other and the material world. Of importance are the ways gestures and actions are performed and made meaningful in particular social settings through which naturalness is achieved.*" The aim of the embodied interaction perspective is not to dismiss the positivist approach, but to present other directions that have potential for innovation.

As we can see, defining what natural means, in the context of Human-Computer Interaction (HCI), is challenging, and literature does not present a consensus. In particular, one phrase from Malizia & Bellucci [83] deserves attention: "*Imposing a standard, especially when it is about cultural topics (such as gestures), can easily fail due to natural differences among human beings.*" If differences are natural between people, then being natural means dealing with differences. Story et al. [124] emphasize how important it is considering diversity in the design process: "*Designers are trained to design for a mythical 'average' group of people, but in fact this group does not exist. Every individual is unique and as a group, the human species is quite diverse.*"

Accessibility is the area that entails taking care of various user needs. Usually, as Emiliani & Stephandidis [36] highlight, it is traditionally associated with designing computer systems that are accessible to people with disabilities, and a common approach is to add an Assistive Technology (AT). Such strategy means giving people with disabilities access to systems originally designed for non-disabled users. Another approach would be that of Design for All or Universal Design (UD), which Story et al. [124] describe as the following: "*It is possible to design a product or an environment to suit a broad range of users, including children, older adults, people with disabilities, people of atypical size or shape, people who are ill or injured, and people inconvenienced by circumstance. This approach is known as universal design. Universal design can be defined as the design of products and environments to be usable to the greatest extent possible by people of all ages and abilities. Universal design respects human diversity and promotes inclusion of all people in all activities of life.*"

In the context of computer systems, this design philosophy is also known as Universal Access, like Emiliani & Stephandidis [36] describe: "*Universal access implies the accessibility and usability of information technologies by anyone at any place and at any time.*" It is important to note, however, that AT and UD are not opposites: "*Universal design strives to integrate people with disabilities into the mainstream and assistive technology attempts to meet the specific needs of individuals, but the two fields meet in the middle.*" [124]. Hence, we understand Accessibility as this middle ground between Assistive Technologies and Universal Design; the ultimate goal is to make information technology and computer systems accessible to the greatest possible extent of people.

However, while literature presents various perspectives on what natural means in the context of HCI, the way they approach the intrinsic differences between people is still rudimentary, as Accessibility does not seem to be a part of the definition of Natural User Interfaces. This issue becomes even more important if we consider the constant evolution process that is making technology increasingly more invisible. The vision of ubiquity and pervasiveness proposed by Weiser [134] is coming through, and it has implications for interpersonal relationships: "*By pushing computers into the background, embodied virtuality will make individuals more aware of the people on the other ends of their computer links.*" This increase in awareness of others emphasizes the importance of inclusion, since, as the barriers to technology are lowered, more differences need to be accommodated.

Therefore, the main research questions we address in this thesis are the following:

1. How to characterize Natural User Interfaces (NUIs) in the context of a constantly evolving technology?

2. How to make NUIs accessible to all, considering the same technological context?

These questions are aligned with two of the Great Challenges identified by HCI researchers in Brazil [13]. On the one hand, Challenge 2 [43] describes the difficulty of designing systems for the complex ecosystem composed by different devices and people with a variety of needs and abilities. This challenge, then, has not only technological implications, but also social, cultural and economical, for instance. Particularly for the Brazilian context, removing material, cognitive and affective barriers is a requirement to fully work towards human development. On the other hand, Challenge 3 [44] is about the continuous growth in the variety of ways of interaction that arise from the emerging technologies. In particular, this challenge raises questions about how theoretical models could promote natural interaction, by considering aspects of Accessibility and difference, in a non-deterministic way. Therefore, these two challenges permeate our research questions, which show evidences of the relevance of this thesis for HCI research, also in the Brazilian context.

1.0.1 Objectives

Considering the presented ideas and the proposed research questions, the **main** objective of this thesis is to investigate, design, develop and experiment with several NUI systems aiming at accessibility for all. To do so, we planned to use a variety of technologies that might be considered to offer natural interaction, such as touch and gesture. However, we also intended to investigate other technologies, especially ones that can provide pervasiveness like proposed by Weiser [134], or ones that can go towards “embodied interaction”, as proposed by O’Hara et al. [100].

Therefore, our **specific** objectives are the following:

- Design and develop NUI systems following the Universal Design philosophy, therefore making them accessible to as many stakeholders as possible.
- Experiment the proposed NUI systems with different stakeholders, in particular ones with disabilities, so that we can test and improve their accessibility.
- Investigate with as many technologies as possible to design and develop accessible NUI systems.
- Propose a characterization for NUI, considering the investigated aspects of technology and Accessibility. The characterization might be in the form of a theoretical framework, heuristics or dimensions of naturalness.

1.0.2 Research Method

To achieve our objectives, we followed the design approach known as Semioparticipatory [14], which adopts a systemic view of technology’s role in society. In order to accomplish this, Organizational Semiotics (OS) [71] serves as a theoretical framework, since it allows to look at stakeholders and the structure of meanings they create with and within information systems. Furthermore, the semioparticipatory approach is fitting to our objectives as it welcomes and encourages bringing together a plurality of worldviews and experiences into the design process. Hence, such approach is aligned with our goals of following Universal Design and of involving different stakeholders in the design and development of NUI systems.

The semioparticipatory approach also applies a set of participatory techniques and artifacts, based on both OS and Participatory Design (PD). The latter is a design philosophy that advocates for democracy in the design of products and computer systems [113], and there are several ideation and design techniques to achieve that [92]. This way, the design process becomes a social practice, where the artifacts and techniques serve as a communication channel between the participants, in a way that is inclusive even to people who are not familiarized with Information and Communication Technology (ICT).

Joining our goals with the semioparticipatory approach, in this thesis we adopted the following process, which is depicted in Figure 1.1:

1. **Concept of NUI:** find or propose a concept for NUI or for natural interaction;
2. **Design Proposal:** materialize the concept of NUI in the form of a system;
3. **Experiment with the Proposal:** test the NUI system with stakeholders;
4. **Review the Concept:** reconsider the initial NUI concept, based on the results of the experimentation; the result will be a new concept of NUI, restarting the cycle.

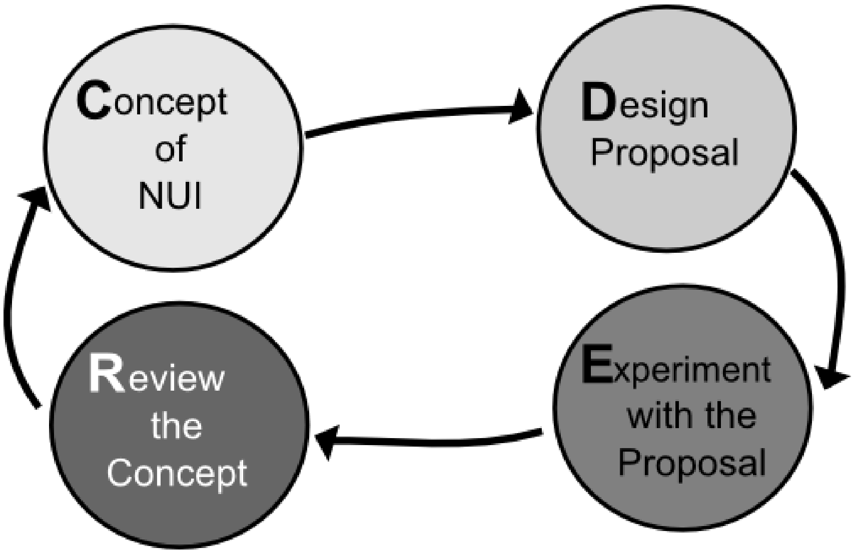


Figure 1.1: Process adopted throughout the thesis.

The semioparticipatory approach permeates the entire process. The systemic view of design, along with our objectives, helped to define the steps. Furthermore, the participatory artifacts and techniques can be applied in any of the stages, allowing stakeholders to participate at any point.

1.0.3 Thesis Organization

This thesis is organized in seven chapters – aside from this Introduction and the Conclusion. Each chapter either was already published or is to be published in the near future, as part of conference proceedings or as journal articles. Finally, the thesis also has five appendices. Next, we detail each chapter's contribution.

- **Chapter 2: Natural User Interfaces in the Context of Accessibility: A Systematic Review** Abstract: "*Natural User Interfaces (NUIs) represent a new interaction paradigm, with the promise of being easier to use, or more intuitive than its predecessors. Along with such promise, the growing adoption of this paradigm means the diversity of people with access to it will also increase. However, this raises the question of how can NUIs indeed be usable to everyone, even those in special conditions? In this paper we seek the answer to this question through a systematic literature review, following the PRISMA protocol. From the 521 results, 98 passed our eligibility criteria, and were analyzed through data extraction. Our analysis gives an overview of the state of the art of NUIs in the context of Accessibility, as well as points to interesting literature gaps.*"

  This chapter presents a systematic literature review, where we analyzed papers with NUI solutions in the context of Accessibility. In terms of our research questions, this chapter helps us to have an overview of the state of the art of the problem we are trying to solve. It also points to literature gaps, helping us to emphasize the importance and novelty of this thesis.

This chapter will be submitted for review to the journal "Universal Access in the Information Society", by Springer, in Dec. 2018.

- **Chapter 3: Heuristics for NUI Revisited and Put into Practice**

  Abstract: "*Natural User Interfaces (NUIs) represent a strong tendency for interaction with new computational technologies. They also represent a big challenge for designers, since delivering the promised feelings of naturalness is not trivial. In this paper, we revisit a set of 23 heuristics for NUI applications within the context of three experiments to evaluate the design of two scenarios of using NUI as assistive technology systems. While using the initial set of heuristics, they also were evaluated. Results of the experiments led to a leaner set of 13 NUI heuristics, with a compliance scale ranging from -4 to 4. The heuristics in the revisited set were defined, described and illustrated in the context of the experiments, so that they can be useful for designers and evaluators.*"

  In this chapter we present our first attempt at characterizing NUIs in the context of Accessibility. To do so, we proposed a set of usability heuristics for NUI, and applied them as evaluation tools in practical scenarios. Hence, this particular work used the lens of the classic HCI paradigm, where the concerns are based on ergonomics and ease of use. It seems in line, then, with what O'Hara et al. [100] called the "positivist" perspective on naturalness. This chapter represents, therefore, a step towards answering our research questions, but the first one in particular, since we are using a conventional approach from the field of HCI to characterize NUIs.

  This chapter was published as a full paper in the 2015 Human-Computer Interaction: Interaction Technologies (HCII 2015) [81].

- **Chapter 4: Designing Natural User Interfaces Scenarios for All and for Some: an Analysis Informed by Organizational Semiotics Artifacts**

  Abstract: "*The design of Natural User Interface (NUI) technologies is still in its early stages; therefore, it does not have well-established guidelines, especially ones that consider the context of Accessibility. This increases the challenges for designers of these technologies to achieve products fulfilling their purpose. In this paper we present a research project that aims at exploring NUI devices within the Accessibility context, with the goal of proposing ways to promote a better design for NUI technologies. We present this project from an Organizational Semiotics perspective, so that the context we aim to focus on shows itself clearly during the entire design process. Our ultimate goal is to promote better NUI designs, especially for people with disabilities, supporting their autonomy and inclusion in society.*"

  This chapter presents an overview of the research idea behind this thesis, structured in the Organizational Semiotics artifacts. In particular, using the Semiotic Framework (SF) [123] allowed us to see that, depending on the level of the SF we begin the design of a NUI (bottom or top), in the end we either achieve an Assistive Technology, or a Universal Design. To support this analysis, we used three practical scenarios. Two of them had the assistive technologies that were also presented in

Chapter 3. The other scenario addressed Universal Design, and it is presented in detail in Chapter 5. In terms of our research questions, the work presented in this chapter is another way of characterizing NUIs, but now with a stronger emphasis on the context of Accessibility.

This chapter was published as a full paper on the 2015 International Conference on Informatics and Semiotics in Organisations (ICISO 2015) [77].

- **Chapter 5: A Smart Supermarket must be for All: a Case Study Including the Visually Impaired**

  Abstract: "*Shopping in the supermarket is a necessity in modern life. This task, however, can be a challenge for people with disabilities, making them dependent on relatives or supermarket employees to aid them. In this paper, we investigate the subject by proposing and experimenting a system that takes advantage of current ubiquitous computing to support all customers in finding and selecting products in a supermarket. Based on the Internet of Things (IoT), this system is embedded in a mobile platform. A case study conducted with users – including visually impaired ones – is reported and discussed. The results are compared with previous experiments conducted with users without disabilities, revealing the impact the system has in terms of efficiency, and feelings of satisfaction, control and motivation.*"

  In this chapter we present the NUI scenario of a smart supermarket, which we designed, developed and experimented with, applying the Universal Design philosophy. This work has many types of contributions. First, technological ones, as it proposes an affordable solution for a smart supermarket, using Radio-Frequency IDentification (RFID) and the Internet of Things (IoT), in a reasonably priced manner. Second, it moves forward with the characterization of NUI, now bringing it into a scenario of ubiquitous technology, and with a formal experimental setup and rigorous statistical analysis of quantitative results. Fourth, it is a proof-of-concept of how Universal Design can be used with NUIs, thus bringing forth the characterization of both NUIs and the context of Accessibility, the two main concerns of our research questions.

  This chapter was published as a full paper in the 15th Brazilian Symposium on Human Factors in Computing Systems (IHC 2016) [78].

- **Chapter 6: A Memory Game for All: Differences and Perception as a Design Strategy**

  Abstract: "*In this paper, we present a literature analysis of accessibility in games based on Natural User Interface (NUI). We also present a case study where we made an adaptation to the traditional memory game and tested it with four visually impaired people. This adaptation was conceived from a Universal Design perspective, and employed NUI. The analysis of both literature and the case study allows us to propose a design strategy for natural interactions for all.*"

  In this chapter we began to walk towards what O'Hara et al. [100] characterized as the "embodied interaction", adopting a line of inquiry beyond the classic HCI. We present a new theoretical background to help us characterize NUIs in the context of Accessibility. More specifically, we present the concept of affordances from James Gibson [50], and a philosophical stance on differences, as proposed by Gilles Deleuze [32]. The first reference, being related to perception and the relationship between a subject and a system, represents an answer to our first research question, regarding the characterization of NUI. The second reference, Deleuze [32], deals with matters of differences and inclusion, so it is related to our other research question, about the characterization of Accessibility in the current technological context.

This chapter was published as a full paper at the 17th Brazilian Symposium on Games and Digital Entertainment (SBGames 2018) [79].

- **Chapter 7: An Enactive Perspective on Emotion: a Case Study on Monitoring Brainwaves**

  Abstract: "In the growing field of ubiquitous computing research, there has been an understandable need to revisit the concept of a standard interface with goal-targeted conscious interaction. An enactive system, which draws on a phenomenological perspective, has as a core concept the dynamically coupling of mind and technology, where the interaction design is not goal-oriented, but driven by non-conscious control of the system. In this paper, we investigate the possibilities of the sensor measurements of an EEG device to in fact potentially contribute to the design of an enactive system. We then take the results of such exploration and look at them through the lens of the enactive approach to cognition and its perspective of emotion and cognition as intertwined. This perspective leads our discussion on how to bring the design of enactive systems closer to supporting, through interaction, the social and cultural construction of emotion."

  In this chapter, we present a case study with a NUI device that reads brainwaves, and within it we reflect upon theoretical concepts of enaction presented by Thompson & Stapleton [127], and upon the concept of enactive systems, proposed by Kaipainen et al. [60]. These reflections have a two-fold contribution for answering our research questions. First, they enable us to further expand our theoretical reference for characterizing NUI, which we started on Chapter 6; now we added the concept of enaction. Second, we reflected upon how the enactive and ubiquitous scenario we presented could harbour Universal Design. Therefore, we worked on both of our research questions.

  This chapter was submitted for review to the 21st International Conference on Human-Computer Interaction (HCII 2019).

- Appendix A: Organizational Semiotics Artifacts Filled In
- Appendix B: Original NUI Heuristics
- Appendix C: Forms for Using the NUI Heuristics (English and Portuguese)
- Appendix D: Ethics Committee Documentation

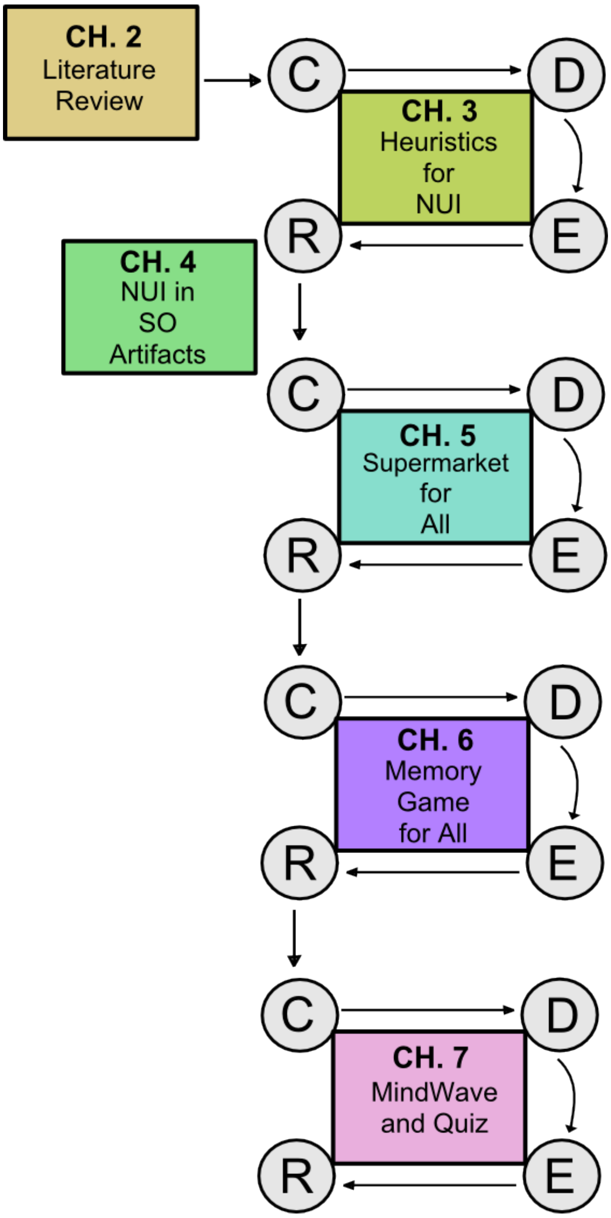


Figure 1.2: The thesis process within the chapters.

- Appendix E: Authorizations for Using Published Articles

The summary of the chapters' general view is represented in Figure 1.2. The process from Figure 1.1 is underlying in Figure 1.2, illustrating how each chapter either composed an entire iteration of the process cycle, or represented one of its stages.

Chapter 2

Natural User Interfaces in the Context of Accessibility: A Systematic Review

2.1 Introduction

The development of widespread technologies based on interactions different from the conventional mouse and keyboard has given birth to a new paradigm, named Natural User Interface (NUI). Examples of such technologies are the touchscreen smartphones and tablets, or the gesture-based Microsoft Kinect. In fact, [12] popularized the term NUI when unveiling the Kinect (then named "Project Natal") and praising NUI as a way to make technology a partner, not a tool. In the same year, [98] criticized the term, calling it more marketing than reality, because gestures are neither natural nor easy to learn or remember. [100] partially agree with this critique, arguing that the term "natural" has been overused but that it can also inspire new research and development.

In this sense, to the research field of Human-Computer Interaction (HCI), these innovations have created an ecosystem composed of new technologies and of people with different needs and difficulties that need to be able to use these devices [13], in ways that actually feel natural. Thus, this ecosystem represents a two-fold challenge: creating interfaces that are indeed natural, and promoting the inclusion of a widest as possible array of users.

The first part of this challenge lies in the definition of "natural". It is a term that has been used with greater regard for the kind of technology employed than for the actual feeling of "naturalness" it provides to the users [62, 83, 100]. In particular, [62] says that NUIs are well-designed interfaces that allow fluid interaction with computers, in contrast with the indirect forms of input provided by the mouse and the keyboard.

The second part of the challenge refers to Accessibility, i.e., taking into consideration varied user needs, such as disabilities, literacy, age and culture. Culture alone is a complex issue, in the field of gesture-based interactions [83].

Therefore, to get a better view of this challenge, in this paper we present a systematic review of literature in the theme. This review followed the PRISMA Statement [68] and, hence, our paper is organized according to its recommendations: in the following subsections, we will present the rationale and the objectives of our work, then, in the next section, we will explain the method we adopted, followed by results and, finally, our conclusions.

2.1.1 Rationale

In theory, Natural User Interfaces (NUIs) offer easy and seamless interactions to their users. If this theory is correct, NUIs have the potential to bring important contributions to the context of Accessibility, given they could be more inclusive than the traditional Graphical User Interface (GUI).

Therefore, this systematic review aims to shed light on how NUIs can be used in the context of Accessibility. We consider that this "context" includes not only Accessibility per se, but also the following concepts:

- **Assistive Technologies (AT)** are solutions to help individuals with specific disabilities in well-defined tasks.
- **Universal Design (UD)** refers to solutions that are usable by any kind of person, without the need for adaptation and regardless of characteristics such as disability, gender, age and culture. Is is also known as "**Design for All**".
- **Accessibility** is a general terms that refers to solutions that are accessible to people with various kinds of needs and abilities.

As stated by Norman [98], gesture-based interfaces (and, as we believe, other types of NUIs) are the path to a more holistic and human interaction between people and technology. However, Norman also said that, in order to get there, it would take work, time, attempts of pattern creations and accommodation of users' handicaps. Almost ten years later, we seek to find out how far we have come down this path.

2.1.2 Objectives

The main goal of this systematic review is to answer the following research question: *How to design NUIs in the context of Accessibility?*

To achieve this goal we will search for papers that treat NUIs not only in the "context of Accessibility" explained in the previous subsection, but also in the research area of HCI. This means we seek works that both analyze NUIs and their aspects of Accessibility, Assistive Technologies, or Universal Design (and Design for All).

Our goal also implies that we need to look for papers that explicitly show concern for inclusion or assistance to different types of users. This does not refer exclusively to people with disabilities; it can also mean accessibility in terms of, for instance, language, culture or age. This way we intend to guarantee that our study includes only papers that have some contribution to both fields of NUI and Accessibility.

2.2 Method

The following subsections provide details about the method used in this systematic review. The section names are required by the PRISMA protocol [68].

2.2.1 Eligibility Criteria

This systematic review included only papers that met both eligibility criteria:

1. **NUI as the focus of the work:** works that explicitly use the term "Natural User Interface" in their text, title, abstract, or keywords (and not only in their references).

2. **Context of accessibility characterized:** papers that explicitly use at least one of the terms "Accessibility", "Assistive Technology", "Universal Design" or "Design for All" in their text, title, abstract, or keywords (and not only in their references).

2.2.2 Information Sources and Search

To perform our search, we used the tool called "*Publish or Perish (PoP)*" [55]. We used this tool for two reasons. First, because, although we chose Google Scholar as the search engine, through PoP we can export the search results, hence facilitating the analysis and sharing of results. Second, since each digital library has its own search engine, concentrating the search into one tool avoids having to use different search strings for each database.

However, there were some minor adjustments we had to make. First, we had to do two separate searches, one using the keyword "Natural User Interface", and the other, "Natural User Interfaces". We noticed that ignoring the singular of the term left some papers out of the search. Second adjustment was performing the search in the Springer database separately, through the database's own engine. This was necessary because the Google Scholar search engine would bring several results from Springer that had the keyword "Accessibility", simply because the term appears at the footer of every Springer database webpage.

These were the main digital databases where the search was performed:

- **ACM Digital Library**[1]
- **IEEE Xplore**[2]
- **Elsevier**[3]
- **Springer**[4]
- **CiteSeerX**[5]

The last search was performed on April 1st 2018. We used the following search string:

```
(‘‘Natural User Interface’’ OR ‘‘Natural User Interfaces’’)
AND
(‘‘Design for All’’ OR ‘‘Universal Design’’
OR ‘‘Assistive Technology’’ OR Accessibility)
```

[1] http://dl.acm.org
[2] http://www.ieee.org/ieeexplore
[3] http://www.sciencedirect.com
[4] http://www.springerlink.com
[5] http://citeseerx.ist.psu.edu

Therefore, we constructed a search string that aimed at finding records that approached our two eligibility criteria.

Finally, we also applied search filters for publication year (no older than 2008) and for publication type (only conference proceedings and journals).

2.2.3 Study Selection

After the search was completed and duplicates were removed, we opened each publication file and made a text search for the terms of the search string (i.e., "Natural User Interface", "Accessibility", "Assistive Technology", "Universal Design" and "Design for All"). This way, we could evaluate whether the paper appeared on the search only for having a reference where one of the terms appears. This analysis was conducted in order: criterion #1 was evaluated first, then criterion #2. If the paper did not meet criterion #1, it was immediately excluded.

In case the papers actually used the terms in their text, we would then see if they were used just as an example, and not an integral part of the research. In this case, the paper would be excluded. We also excluded records such as editorial notes, workshop descriptions, or full proceedings.

We identified some replications of studies across the search results, meaning that we found a few cases where two or more papers talked about the same system design or the same research project. This was not considered an exclusion criterion because we believed each paper had its own contribution, and it was not up to us to evaluate that.

2.2.4 Data Collection Process

All the papers that passed both eligibility criteria went through the data collection process. To aid us in this stage we created a data extraction sheet. It contained the information we thought would provide an overview of the current state of the art of research on NUIs in the context of Accessibility.

2.2.5 Data Items

The variables we sought in each selected record were the following:

- **Concept of NUI:** how the term "Natural User Interface" appears in the text; full copy-and-paste of the relevant paragraph(s), for later making of a word cloud.

- **Accessibility Terms:** multiple selection between Accessibility, Assistive Technology, Universal Design and Design for All, meaning it is possible for the same paper to have more than one of these values.

- **Accessibility in Context:** how the terms identified in the previous variable appear in the text; full copy-and-paste of the relevant paragraph(s), for later making of a word cloud.

- **Abstract:** full copy-and-paste of the paper's abstract, for later making of a word cloud.

- **Keywords:** full copy-and-paste of the paper's keywords, for later making of a word cloud.
- **Title:** full copy-and-paste of the paper's title, for later making of a word cloud.
- **Type of Work:** subjective categorization, based on the goals, objectives and results presented by the paper; for instance, it can be a theoretical framework, or the design of a NUI system. The same paper can have more than one Type of Work.
- **Audience:** subjective categorization, based on the main group(s) of user(s) the the paper explicitly addresses. When this information was not present, we wrote "Unspecified". The same paper can have more than one Audience.
- **Context:** subjective categorization, based on the the kind of location or task the paper identifies as the focus of their proposal. When this information was not present, we wrote "Unspecified". Each paper only had one Context.
- **Technologies:** text field to identify the specific technologies that were employed in the paper. When this information was not present, we wrote "Unspecified". The same paper can have more than one Technology.

2.2.6 Summary Measures

For each of the variables "Concept of NUI", "Accessibility in Context", "Abstract", "Keywords" and "Title", we created a word cloud to graphically highlight the most used terms of the texts that were collected. We also performed a numerical analysis of the most frequent terms, and of correlation between words.

For the other variables, we counted the occurrences of their input values.

2.2.7 Synthesis of Results

We conducted a qualitative analysis of the word clouds generated, along with a simple statistical word correlation analysis. For each word cloud, we excluded irrelevant terms, like prepositions and common verbs. We also excluded terms that were obviously gonna be frequent. For instance, for the variable "Concept of NUI", we excluded the words "natural" and "user".

We also performed a quantitative analysis on the input values of the extraction sheet, allowing us to make graphics that helped in our qualitative analysis of these variables.

2.3 Results

In the following subsections, we present the results of our systematic review.

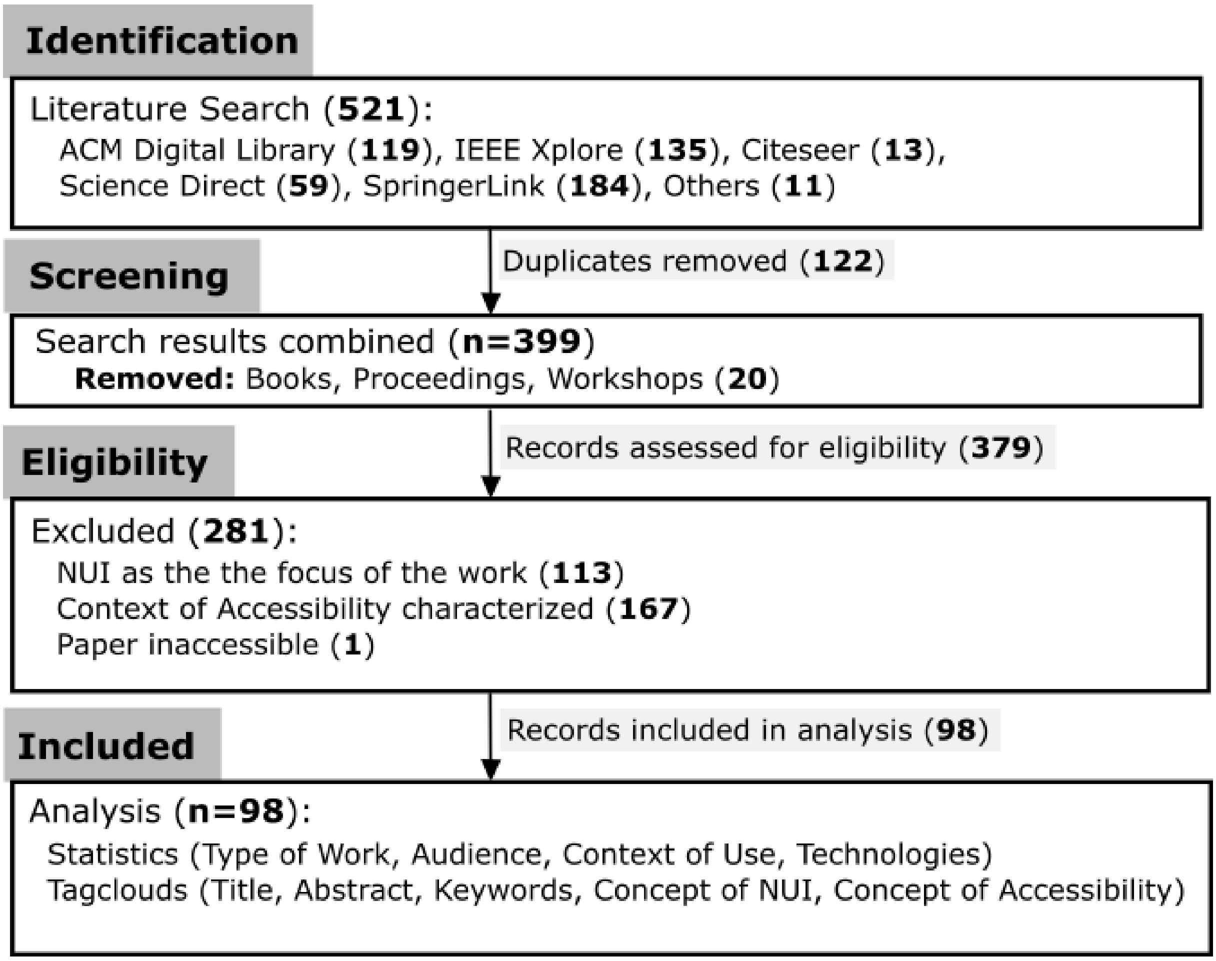


Figure 2.1: Workflow of the study selection process.

2.3.1 Study Selection

After searching the digital databases we got a total of **521** results: **119** from ACM, **135** from IEEE, **13** from CiteSeerX, **59** from Elsevier, **184** from Springer, and **11** from other databases Google Scholar searched.

We found **122** duplicates and removed them, leaving **399** papers for the screening phase, where **20** more were excluded for being proceedings, books, workshop descriptions, or editorial note. From the remaining **379**, we excluded **281**: **113** for not meeting the first eligibility criterion (NUI as the focus of the work), **167** for not meeting the second criterion (Context of accessibility characterized), and **1** for being inaccessible (we would have to pay to be able to read it).

This left **98** records to be analyzed. We performed quantitative and qualitative analysis from the input values of the data extraction sheet. Fig. 2.1 summarizes this process in the a workflow.

2.3.2 Synthesis of Results

In this section, we present the results of our systematic review, organized by the data we extracted from them.

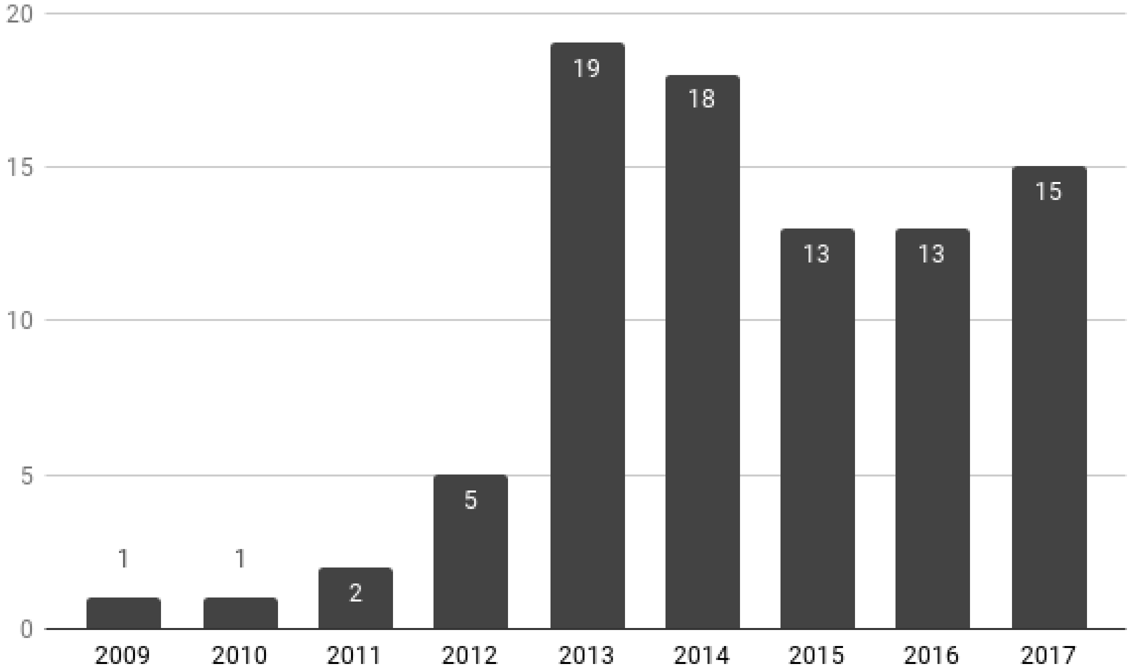


Figure 2.2: Distribution of publication years of the selected papers.

Publication Year

We summarized the information about publication years from the **98** selected records in Fig. 2.2.

It is interesting to note that the number of publications started to rise in **2013**, three years after the announcement of the Kinect [12]. That was also the year where the number of publications reached a peak, after which it declined a bit and maintained a relative stability.

Accessibility Terms

We counted the amount of times the terms "Accessibility", "Assistive Technology", "Universal Design" or "Design for All" were employed in the papers, and the results are shown as a Venn diagram in Fig. 2.3.

We highlight that the number of papers from the set of Universal Design and Design for All is very small – only **13** papers in total – and that is combining the two terms. The **3** papers that deal exclusively with this theme are the ones from [35], [21], and [102]. In addition, the **4** that have both Universal Design and Accessibility are the ones from [2], [141], [78] and [6]. Finally, the **6** papers that use all terms are these: [125], [107], [84], [16], [8], and [77].

It is also interesting to note that no papers deal exclusively with Assistive Technology and Universal Design at the same time.

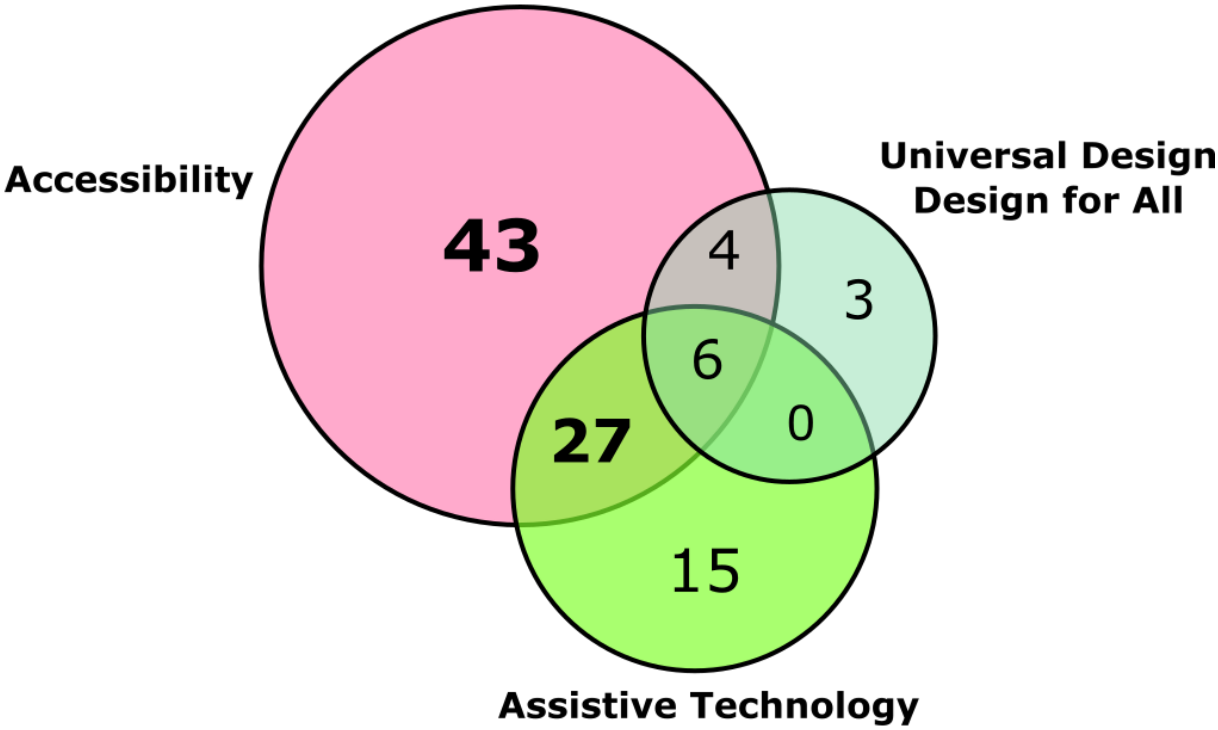


Figure 2.3: Venn diagram of how many papers employed each of the Accessibility terms.

Type of Work

After categorizing the papers according to their objectives, methods and contributions, we counted how many fit into each category. The results are summarized in the bar chart in Fig. 2.4.

We highlight that the majority of the works is the proposal of a NUI System, with a total of **45** in such category. The second most common category, with **18** papers, was "Usability Evaluation", which comprises of studies that apply metrics and usability methods to evaluate interfaces or input methods. Next, we have **14** works that propose an Architecture to support NUI systems, which refer to either technological infrastructures, or conceptual architectures.

Going back to the categories with fewer papers, we have **7** literature reviews ([80, 125, 16, 27, 9, 101, 116, 126]), **6** theoretical frameworks ([6, 54, 30, 114, 3, 56]), **5** design guidelines ([86, 102, 23, 80, 81]), and **4** teaching methods ([140, 141, 25, 84]).

Audience

After reading through the papers to find out what are the audiences their proposals are for, we counted how many types appeared. Results are summarized in Fig. 2.5. Some audiences were grouped according to type of disability (motor, cognitive, or visual), but some conditions were kept specific because they might cause more than one type of disability (e.g. Autism, Post-stroke patients). There were also papers that classified their audience as "People with disabilities", so we created a category just for those.

First interesting aspect to note is that there are **23** papers where the audience was not specified. This could either mean no specific audience was considered by the authors,

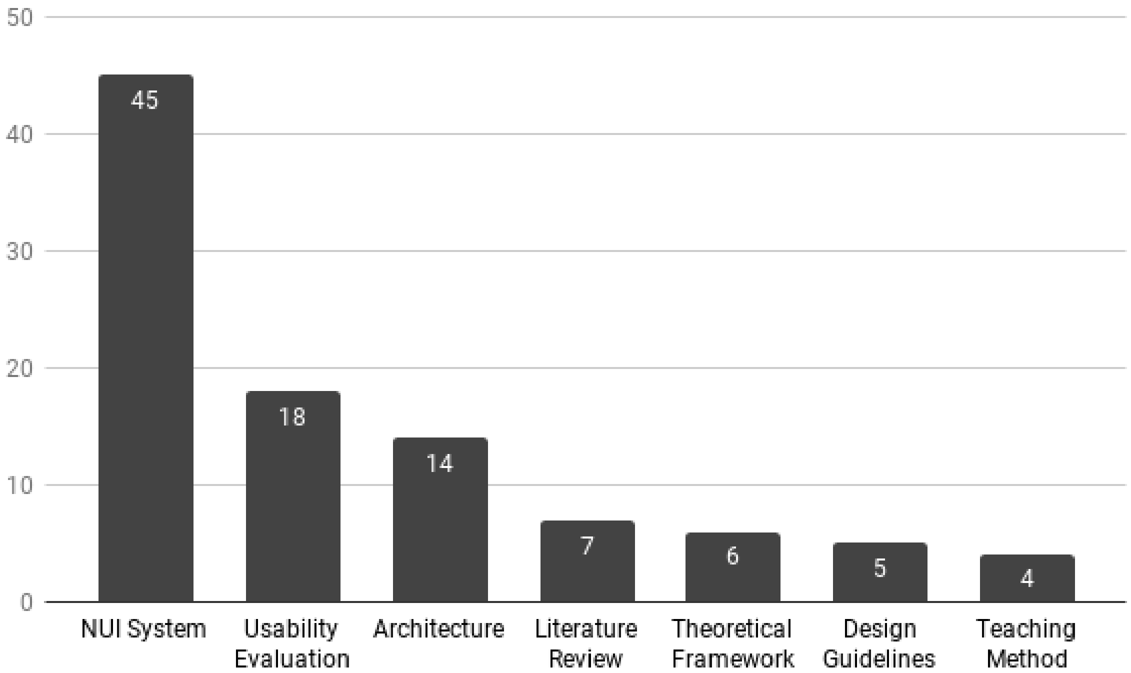


Figure 2.4: Types of work, categorized based on their goals, methods and contributions.

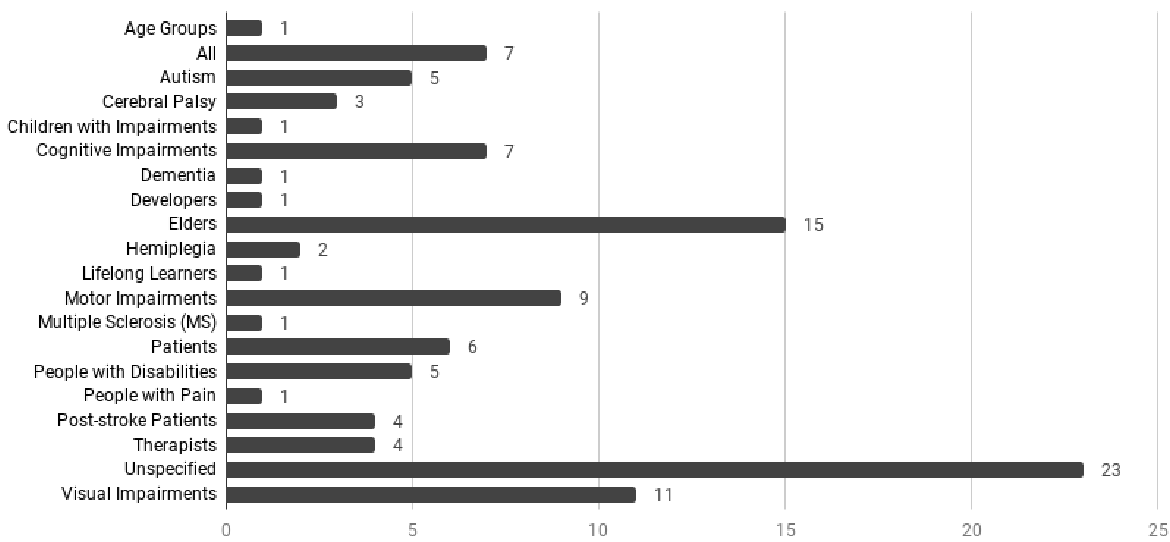


Figure 2.5: Categories of audiences identified in the selected papers.

or that their work is meant for all. If the latter case ever happened, the aspect of being "for all" was not explicit in the text.

We would also like to highlight the categories with only one paper. First, [10] propose a NUI system to help in the rehabilitation of people with "Acquired Brain Injury", which, according to the authors, happens "mostly after a stroke or an accident". Then, [24] performed a usability study to compare the use of several input modalities by three "age groups": children, young adults and elders. On the other hand, [6] say their solution is meant for all, but are specially thought for "children with disabilities". A similar case is that of [78], which propose a system with Universal Design, but tested it with visually impaired people.

Continuing with the cases with just one paper, [8] specified people with "dementia" as their audience. Then, [34] proposed a system that uses the Kinect to make a development environment more accessible. "Life-long learners" is the audience for the RFID system proposed by [126]. [85] performed a usability study with people with "Multiple Sclerosis (MS)". [122] propose a NUI system to help "people with pain" in assessing their level of pain.

Context

After reading through each paper, we interpreted which was the proposal's main context of use. This entails either a location, an environment, or a specific task. The results are summarized in Fig. 2.6.

On one hand, there is again a great number of works with "Unspecified" context. On the other hand, there are a lot of unique contexts, which could not be grouped. This is an indication of how it is possible to use NUIs in a great variety of contexts. In addition, it could also be a reflection of the exploratory nature of the studies, as they are proposing solutions to a variety of specific problems.

Technologies

We searched in each papers which technologies are an integral part of their work. We did not include technologies that were mentioned as examples of, for instance, input modalities. The results are summarized in Fig. 2.7.

We can see that a vast majority of the works used the Kinect. After it, the other most explored technologies were smartphones, tablets, and Leap Motion. There was also a considerable number of papers with no specific technology. One interesting technology is the ergometer, used by [91] in a game made to get people involved in the physical exercise of cycling.

Concept of NUI

We extracted parts of text from each paper where they employed the term "Natural User Interfaces", either by giving a definition for it, or just mentioning it as part of the work. Then, we generated a word cloud from these texts, using a package from the R[6] language,

[6] `https://www.r-project.org`

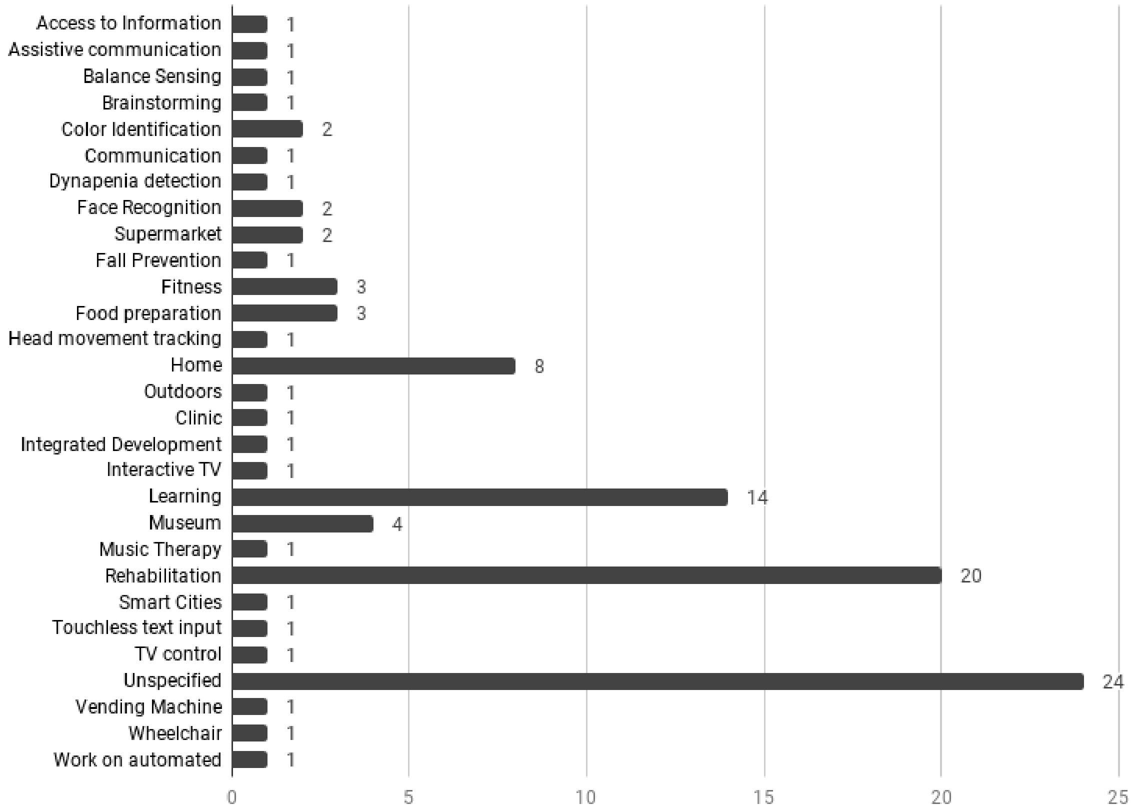


Figure 2.6: Contexts of use identified in the selected papers.

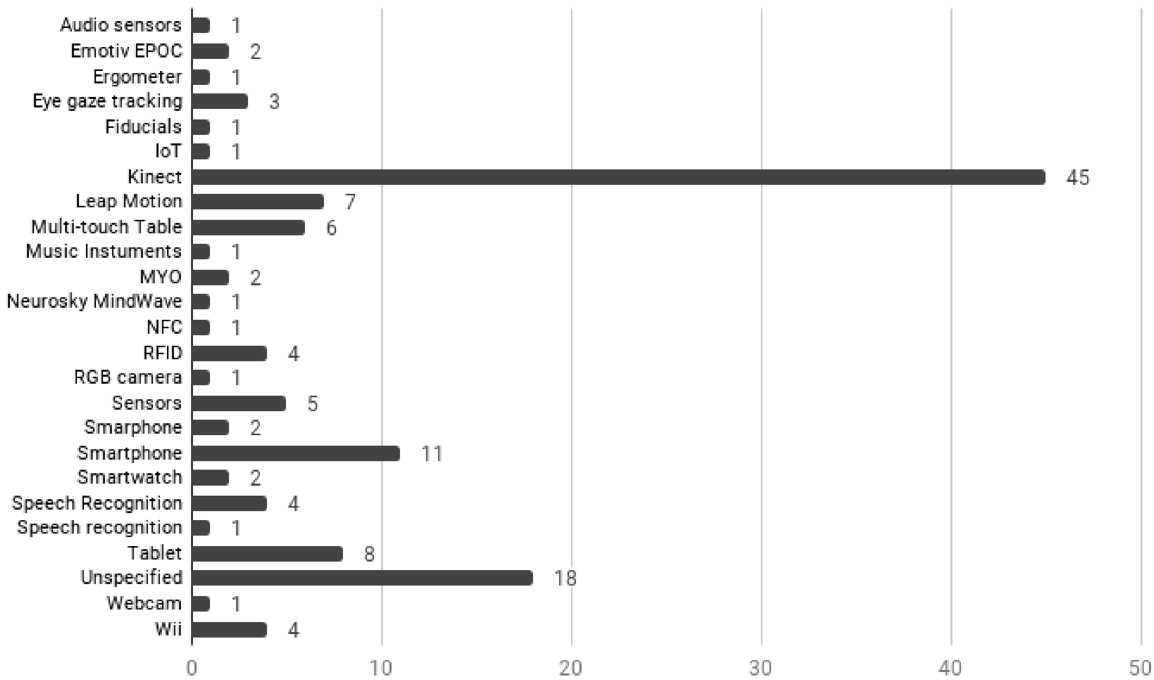


Figure 2.7: Devices, hardware and other technologies identified in the selected papers.

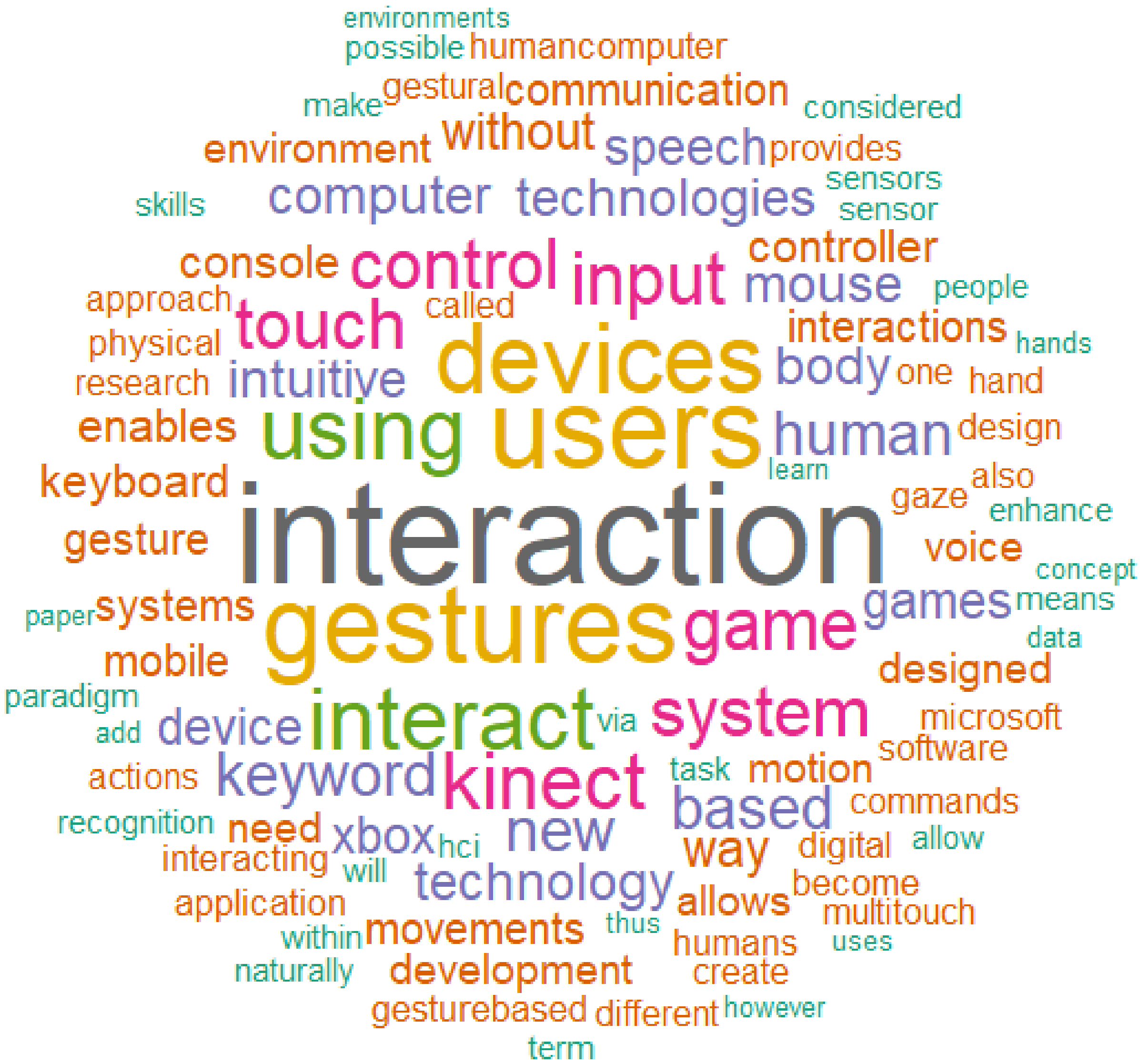


Figure 2.8: Word cloud generated from the text excerpts that used the term Natural User Interface(s).

specific for word clouds. The result is shown in Fig. 2.8.

Words that stand out from the center of the cloud are “gestures”, “kinect”, “touch”, “speech”, and “intuitive”. On the periphery, we see terms such as “human”, “body”, “technology”, and “mobile”. We can also see “mouse” and “keyboard”, which are probably from comparing NUIs with the devices from the GUI paradigm.

Accessibility in Context

We extracted parts of text where the papers mentioned one of the terms from the context of accessibility (i.e., Accessibility, Assistive Technology, Universal Design or Design for All). If the paper mentioned the same term more than once, we chose the term that was more relevant for characterizing the context. In addition, when a paper mentioned more than one term, we extracted excerpts for each term used in the text. When they appeared on the same paragraph, we just extracted that part once. To generate the word cloud, we

Figure 2.9: Word cloud generated from the text excerpts that used the terms from the accessibility context.

used the same process with the R package, and the results are shown in Fig. 2.9.

Words that stand out right away are “people”, “disabilities”, “physical”, “devices” and “design”. We can also see at the center of the word cloud the terms “games”, “assistive”, “usability” and “access”. We input “keyword” when the paper defined one of the accessibility terms as a keyword; since it appears big on the word cloud, a considerable number of papers did that.

Abstract

We took the entire abstract from each paper and processed the resulting text with the same R package to generate a word cloud. The result is shown in Fig. 2.10.

The words that stand out most are “user”, “design”, “system”, “interaction” and “study”. At the center of the word cloud, we can also see “rehabilitation”, “people”, “natural”, “game”, “technologies” and “interface”.

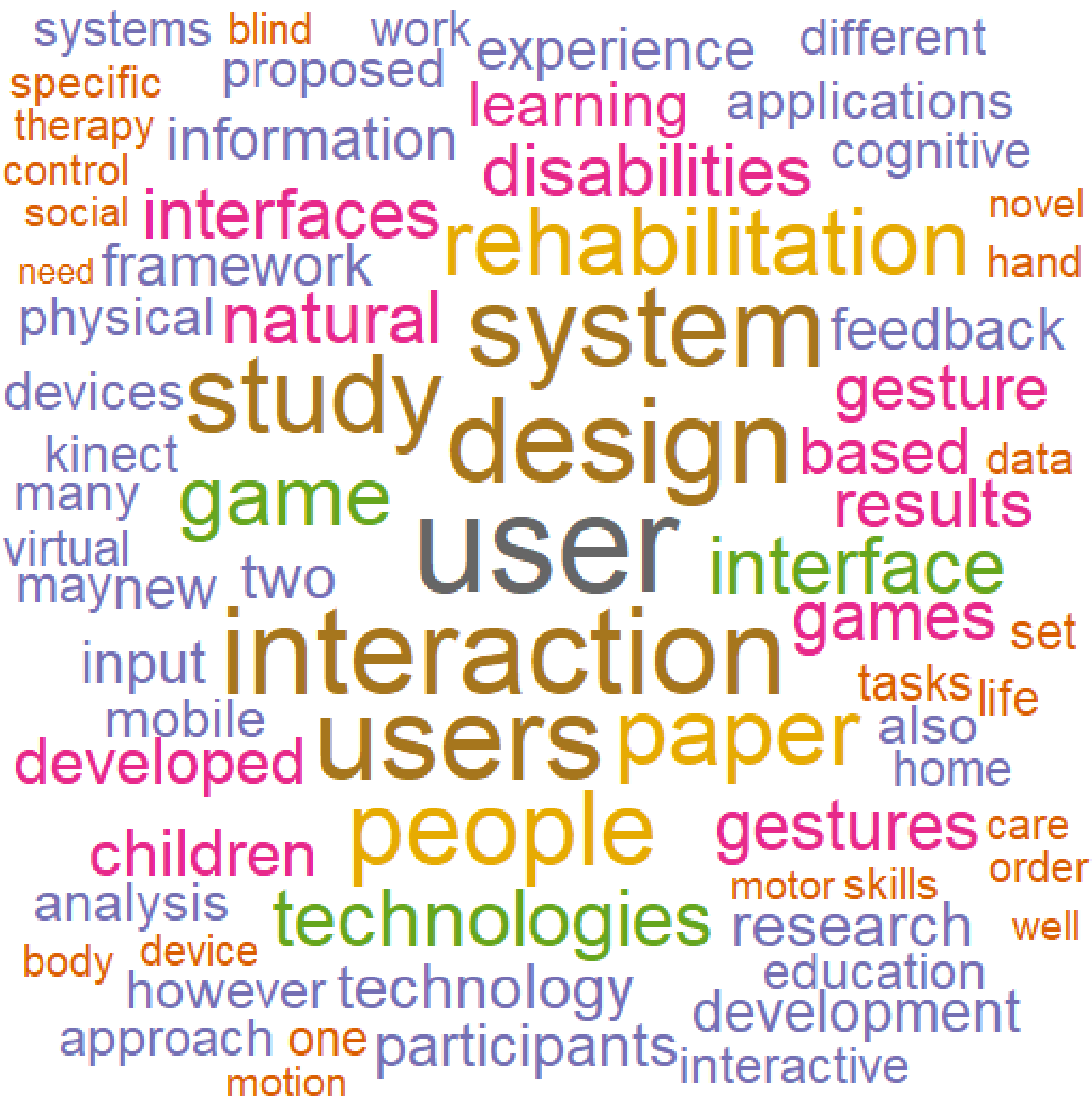


Figure 2.10: Word cloud made from the selected papers' abstracts.

Figure 2.11: Word cloud made from the selected papers' keywords.

Keywords

We took all the keywords defined in each paper and processed the resulting text to generate a word cloud. The result is shown in Fig. 2.11.

The words that stand out most are "natural", "user" and "interaction". Other words that stand out at the center of the cloud are "rehabilitation", "accessibility", "design", "kinect" and "virtual".

Title

We processed all the texts from the selected papers and processed them with the R package to generate a word cloud. The result is shown in Fig. 2.12.

The biggest word in the cloud is "user". Almost with the same highlight are "de-

Figure 2.12: Word cloud made from the selected papers' titles.

sign", "people", "interaction" and "natural". Other words that stand out are "children", "education", "technologies", "impairments", "games", "gesture" and "kinect".

2.4 Discussion

Our main goal with this systematic review was to answer the research question of *How to design NUIs in the context of Accessibility?* We believe our results shed some light on how literature has been trying to answer this question.

In terms of publication year, we see that most papers are in the period between 2013 and 2017. It is interesting that the publications reached a peak in 2013, and after that maintained a relatively constant amount for each year. This could be an indication that the term NUI gained importance in the context of Accessibility in 2013 and remained relevant afterwards.

In terms of the terms that were employed on the papers (Accessibility, Assistive Technology, Universal Design, and Design for All), we can see that the more general term, "Accessibility", has the highest frequency of use. "Assistive Technology" is the second most employed and also shares a great intersection with "Accessibility". The terms "Universal Design" and "Design for All" represent a very small portion of the papers we selected, even when their individual appearances are combined. This points to a literature gap, i.e., there is a deficit of academic works that explicitly follow the Universal Design philosophy.

Regarding the types of work we encountered, we see that the vast majority is proposing new systems that make use of NUIs, which could indicate that most of the works are exploratory, in the sense that they are testing out how NUIs can help in specific situations. Another portion of the papers shows usability evaluations for existing NUIs, which could also indicate an exploratory characteristic, but in the sense of comparing certain interfaces to others, using conventional metrics. The papers that propose architectures for NUI seem to have adopted a generalizing perspective, in terms of trying to offer a solution that would help a great number of designers and developers of NUIs. This indicates attempts at formalizing and helping to establish NUIs as a widely adopted interaction paradigm. The remaining types of work are more aligned with theoretical perspectives, although some of the teaching methods do get very hands-on. This also seems like an attempt at formalization, but more in the sense of maintaining NUIs as an object of study in literature.

In terms of audience, we can see that a lot of papers did not specify an audience. This does not mean, however, that their proposals are adopting Universal Design. Groups that received great attention were elders, and people with specific impairments, such as visual, cognitive and motor. Therefore, compared to the amount of papers that explicitly deal with disabilities, the works that are meant "for all" are very few. This is consistent, however, with the results from the use of accessibility-related terms.

Regarding context, we can see a wide variety of specific contexts, which makes sense with the exploratory nature we explained on the types of works. The same goes for the technologies employed, which also present a considerable variety. The contexts, however, do present a large amount that were left unspecified, while technologies proportionally have fewer (although the number is not much lower). The contexts most used were "Rehabilitation", "Home" and "Learning", which could be an indication of three great areas interested in NUIs with Accessibility: health, home automation, and education. For the technologies, Kinect is present in most of the papers that specified a technology, followed by smartphones and Leap Motion, a device for tracking hand movements. This could be an indication that these are the devices most widely available and with the most potential for being useful in the context of Accessibility.

From the word cloud of the concept of NUI, we can see that NUI is strongly associated with different forms of interaction, like gesture, touch, speech, and those that use the body. The word cloud for the context of Accessibility shows us how it is commonly associated with disabilities, assistive technology and usability. This is consistent with our findings with the other data, like the use of the terms shown in the Venn diagram, and the audiences the papers are directed to.

The word cloud made from the abstracts points to an emphasis on users and on interaction, along with game and rehabilitation, the most common context that we detected in the papers. As for the word cloud of the keywords, aside from the term "Natural User Interaction", we can see an emphasis on design, accessibility, Kinect and rehabilitation. This time, most used terms from both context and technology appeared. Finally, from the papers' titles we can see an emphasis again on rehabilitation and Kinect, but also on user, design, children and technologies.

In summary, we have found that, so far, most of the works of NUI in the context of Accessibility have focused on proposing technological solutions, with an emphasis on helping people with disabilities. One of the literature gaps, then, is the lack of explicit concern with Universal Design, i.e., in proposing solutions that are usable by the widest possible diversity of people. Another gap is in the variety of technologies, since most papers focused on the same devices. This also indicate that, in literature, NUIs are seen more through a technological lens than through a philosophical or cultural perspective. Hence, another literature gap is to adopt such approach to characterize NUIs differently.

2.5 Conclusion

In this paper we have presented a systematic literature review to gain an understanding of what is the state of the art of Natural User Interfaces (NUIs) in the context of Accessibility. Such context includes the general term "Accessibility", but it also refers to "Assistive Technology", "Universal Design" and "Design for All". Therefore, we have performed a search with these keywords on the most prominent digital databases and, from a total of 521 results, we selected 98 studies to analyze.

Our analysis showed, first of all, that the theme is still relevant, as the number of publications have not declined in the past years. Second, we also found there is little work on NUIs with Universal Design, i.e., on NUIs that try to be accessible to greatest possible extend of people. Most current work focuses on Assistive Technologies and on Accessibility in general. Therefore, exploring Universal Design is a literature gap.

Another important aspect we noticed was how NUIs have been strongly characterized in technological manners, be it through specific devices (e.g. Kinect), forms of interaction (e.g. gesture, touch, speech) or the types of work we found (e.g. architectures for NUI, or NUI systems). There is little to no work exploring the actual feelings of naturalness, in more abstract terms, or based on theoretical referentials that go beyond usability and sensory-motor perspectives.

Chapter 3

Heuristics for NUI Revisited and Put into Practice

3.1 Introduction

New technological devices have experimented input and output methods based on gestures, touch, and voice, considered more “natural” for interaction than the conventional mouse and keyboard. The new forms of interaction provided by Natural User Interfaces (NUIs) should evoke the feeling of naturalness in their users, by fitting the executed task to its context, and by meeting the user’s capabilities [137]. This naturalness makes it possible to address a wide variety of contexts. For instance, Nebe et al. [94] propose using a multi-touch table for the management of disaster control, allowing several users to interact with a map at the same time. Renzi et al. [104] propose a serious game with a gesture-based interface to teach music concepts for children. Ringland et al. [106] show how a NUI to create paintings on a projected surface can help children with neurodevelopmental disorders. Finally, Bolton et al. [19] present an exergame that uses virtual reality goggles, a Kinect, and a stationary bicycle so that users can exercise while they play a game based on the concept of delivering news-papers with a bike. Each of these examples employ different input and output methods with distinct purposes and for varied types of users. They all try to make the interactions between users and computers more natural and seamless.

Despite the numerous examples in literature of studies involving NUIs, there is a debate [98, 100] around the use of the term “natural” and its implications in interaction design. We believe, however, that this is an indication that successfully designing a NUI is a challenge that involves more than considerations regarding input and output technologies. Therefore, to face this challenge, a set of 23 heuristics for NUIs were proposed [80]. These heuristics were the result of a systematic literature review that also aimed at finding the state of the art of the use of NUIs to assist people with disabilities. In this paper, we present the results of applying these heuristics in practical contexts of design and evaluation of different NUI applications scenarios. In Section 3.2 we present a description of the experiments we conducted and the main results obtained. In Section 3.3 we show how the original set of 23 heuristics was revisited based on analysis of their use, and we present for each new heuristic a description and an example of use. Finally, in Section 3.4 we present concluding remarks.

3.2 The Heuristics in Practice

The heuristics proposed by Maike et al. [80] were applied in three different experiments involving NUI scenarios; Table 3.1 presents a summary of each experiment. The three experiments also had a common feature: they were all preliminary studies with the goal of finding critical system bugs, technical issues and usability problems in their tested systems.

First, let us detail Experiment 1. It followed these steps:

1. Thirteen participants were registered in the database, with five pictures for each, from different angles and distances. Therefore, two participants were left out to act as unknown.

2. One of the participants volunteered to act as a blind user. Before being blindfolded, this person received instructions on how to access the GFR software through voice commands, and on how to aim the smartwatch to capture people's faces. He was also instructed that his goal was to find and recognize (by their name or as unknown) the people that would be in front of him.

3. In silence, other four participants were placed in front of the blindfolded user, and at least one of them was not registered in the database.

4. The timer started counting and the blindfolded user accessed the GFR application. For each person she found, she must say aloud who she believes that person is, based solely on the feedback received from GFR. Timer stops when the user signalizes she believes she has achieved her goal.

5. Steps 3 and 4 were repeated twice for the same blindfolded user and two different sets of four individuals to be recognized.

6. Steps 2 to 5 were repeated four more times with a different participant acting as the blind user and different sets of people to be recognized.

At the end of Experiment 1, the set of 23 heuristics [80] was used during the debriefing session to discuss the design of the Gear Face Recognition (GFR) system. Additionally, the heuristics themselves were discussed, so that we could figure out if their writing was clear, if they were understandable and if they actually made sense in the context of designing Natural User Interfaces (NUIs) applications. During this debriefing session, the participants reached a consensus regarding a grade for each heuristic; the scale used for the grade was the same proposed by Nielsen [97] for his usability heuristics: from 0 (not a problem) to 4 (meaning a catastrophic problem).

Regarding the GFR system, the main problem pointed out by the participants was that the audio cues to help the user in framing someone's face needed to be more helpful.

Table 3.1: Tested System and Participants of each experiment.

Experiment	Tested System	Participants
1	Gear Face Recognition (GFR) [31], a face recognition software installed in a first-generation Samsung Gear smartwatch. Developed especially for visually impaired users, this software application has the goal of helping them find and recognize people in their surroundings. The software offers several sound cues to help the user when framing a person's face (a voice says "recognizing") and identifying that person from the database (a voice says the recognized person's name) or identifying the person as unregistered (voice says "unknown").	15 Human-Computer Interaction (HCI) researchers from the University of Campinas, Brazil.
2	Gear Face Recognition (GFR) with a few improvements in the face framing audio instructions. In addition, the way to access the application was made easier.	23 graduate students from a Human Factors class in the University of Campinas.
3	A face recognition software that uses the Microsoft Kinect placed on top of a helmet to detect and recognize people in the surroundings of a visually impaired user. The system provides 3D auditory cues to indicate who someone is and where they are located in relation to the user. Besides the Kinect, the system also requires a laptop with high processing power to run the face recognition software. This laptop is placed inside a backpack so the user can carry it hands-free.	9 Human-Computer Interaction (HCI) researchers from the University of Campinas, Brazil.

Regarding the heuristics, participants suggested that the scale of grades could include, besides problems, a positive aspect, i.e., how much the system was in accordance with the heuristic. Additionally, some heuristics could be grouped together since they were understood as semantically similar.

As for Experiment 2, it followed these steps:

1. Students were divided into five groups of four or five participants. Each group was asked to elect a member to act as a blind user, and another to be "unknown" in the database. The remaining members of each group were then registered in the database: three pictures for each person, from different angles.

2. The participant elected to be blindfolded received instructions on how to operate the GFR system. A group of non-blind users was silently placed in front of her. Her

task was to find and recognize all the people who are in front of her, assisted only by the GFR system.

3. The timer started counting and the blindfolded user accessed the GFR application. For each person she found, she must say aloud who she believed that person was, based solely on the feedback received from GFR. Timer stopped when user signalized she had achieved her goal.

4. Steps 2 and 3 were repeated four more times for a different blindfolded user and different groups of people to be recognized.

At the end of Experiment 2, the participants received the set of 23 heuristics [80] to analyze during the experiment. As an after class activity, they were asked to discuss the GFR in the context of the heuristics and reach a consensus for the grades of each heuristic. The applied scale of grades was the same as in Experiment 1, but it also included grading how much the system is adherent to the heuristic: from -1 (adheres the heuristic in a superficial manner) to -4 (completely adheres the heuristic). After the participants submitted their heuristic evaluations, a debriefing session was conducted. During this session, participants suggested that, for improving the heuristics, the option "not applicable" was included in the grading scale.

Finally, Experiment 3 followed these steps:

1. Verify which participants were and which were not registered in the database, since the registration process is time consuming and was made in advance.

2. One participant volunteered to act as a blind user. She received instructions on how the system works, and her main goal: finding and reaching a specific person amid a group of four people. The participant then was wearing the helmet, the backpack and was blindfolded.

3. In silence, other four participants were placed in front of the blindfolded user, and at least one of them was not registered in the database.

4. The timer started counting and the blindfolded user began walking towards the group of people to be recognized, moving her head sideways to scan the room. For each person she found, she had to say aloud who she believed that person was, based solely on the feedback received from the system. The timer stopped when the user signalized she had achieved her goal (success), or when the time reached 2 minutes (fail).

5. Steps 3 and 4 were repeated once for the same blindfolded user and a different set of four individuals to be recognized. 6. Steps 2 to 5 were repeated eight more times with a different participant acting as the blind user.

After the experiment, a debriefing session was conducted. The participants discussed the experiment and the main problems found, trying to analyze them with the help of the set of 23 heuristics [80]. The heuristics themselves were also discussed, aiming at to regroup and rewrite them to better support evaluation. To grade each heuristic, the participants had to reach a consensus using two concurrent scales: from 0 (not a problem) to 4 (catastrophic problem), and from -1 (follows the heuristic in a superficial manner) to -4 (completely follows the heuristic). Therefore, it is the same scale used in Experiment 2, but with the possibility of pointing out problems, and measure how much the system complies with the heuristic.

The main problems pointed out by the participants during the debriefing were the need for regrouping the heuristics, since many of them had very close meanings, and the need to change the grading scale, since having negative numbers representing something positive (following the heuristic) is counter-intuitive. Therefore, the suggested grading would represent the level of compliance with a heuristic and would range from -4 (does not follow the heuristic at all) to 4 (follows the heuristic completely). In this case, 0 would be a neutral evaluation, i.e. there are no indications of neither problems nor heuristic compliance.

3.3 The NUI Heuristics Revisited

The previous section described the use of the heuristics for NUI [80] in three different experiments; each experiment pointed out to improvements that were necessary in order to make the heuristics more understandable and useful. In this section we will present the regrouping and, in some cases, rewriting of the 23 original heuristics. First, we show our criteria in evaluating the need for change in a heuristic. Then, we will give a general view of before and after. Finally, we will present the new heuristics in detail, with practical examples of use.

3.3.1 Change Criteria

The changes in the heuristics were based on both quantitative and qualitative analysis of the experiments results. The quantitative analysis come from Experiments 1 and 2; since both experiments tested the same system but with distinct groups of participants, we decided to compare the grades from these experiments. Hence, we placed the grades from the HCI researchers (one grade for each heuristic) in a table, along with the grades from the Human Factors students (one grade for each group, five in total). Additionally, we colored the grades in a scale of gray: the smaller the number (i.e., the more the system followed the heuristic), the whiter the table cell; conversely, the higher the number (i.e., the more critical a problem was), the darker the cell. The result is in Figure 3.1, where the grades of the HCI researchers are the bottom line of each table. It is important to note that the heuristics regarding "Multiple Users" are not shown in Figure 3.1 because the tested system is not in that category.

Our main goal with the comparison in Figure 3.1 was analyzing the interpretations given for each heuristic by finding divergence or convergence in the grades. This way, a column with a predominant tone of color (clear or dark) shows convergence in the grades, suggesting the heuristic had homogeneous interpretation. Likewise, a column with no color tone predominance indicates that there was divergence in the heuristics interpretation, suggesting possible problems with its writing.

Interaction								
Operation Modes	"Interactability"	Accuracy	Responsiveness	Identity	Metaphor Coherence	Distinction	Comfort	Device-Task Compatibility
-1	0	3	-2	-3	-4	-3	3	-3
0	0	3	2	-3	-3	-2	3	-3
0	0	3	2	3	-3	-2	4	-3
2	3	3	2	3	-2	0	4	-1
3	3	4	2	3	0	0	4	0
3	3	2	1	2	0	0	2	3

Navigation				User Adoption					
Guidance	Wayfinding	Active Exploration	Space	Engagement	Competition	Affordability	Familiarity	Social Acceptance	Learnability
-4	-2	-3	2	-4	-3	-2	-3	-1	-3
0	0	-2	2	0	-2	-2	-2	0	-3
0	0	0	2	0	-2	0	-2	0	-3
0	0	0	2	0	0	2	-2	0	-2
3	2	3	3	0	0	3	-2	3	0
2	3	3	0	2	0	2	1	0	0

Figure 3.1: Specialists' evaluations in Experiments 1 (bottom row) and 2 (first five rows)

The qualitative analysis draws on the comments, suggestions and discussions from the debriefings of the three experiments. These data allowed deeper insights into how the specialists actually understood each heuristic, often corroborating with the quantitative data and possibly providing a reason for the divergence in interpretations. Some examples of this will be given in Section 3.3.3.

3.3.2 Before and After

Prior to detailing the new set of heuristics Figure 3.2 illustrates the process of change. As shown in Figure 3.2, the two heuristics Accuracy and Responsiveness (indicated by the number 1 in the image), were removed. Although both the quantitative and the qualitative analysis did not suggest any confusion related to the interpretation of these heuristics, in all three experiments they pointed to problems regarding algorithmic and technological issues only. For instance, in Experiment 2 many of the participants reported lack of precision in the face recognition software for the Accuracy heuristics (hence, the dark tone of its column in Figure 3.1). Conversely, in Responsiveness, they reported delays in the audio feedback provided by the system.

The four heuristics indicated by the number 2 in Figure 3.2 (Identity, Metaphor Coherence, Distinction and Familiarity) were grouped together mainly because, during every debriefing, there was a clear confusion regarding their difference in meaning. Looking at Figure 3.1, we can see that these heuristics seem to have the same scores, except for Identity, which seemed to be the representative of the system's interaction metaphor problems. However, the qualitative data shows that the four heuristics were used to analyze the same aspect (interaction metaphors). Therefore, they were grouped into one heuristic, Metaphor Adequacy.

Figure 3.2 also shows the grouping of the heuristics Guidance and Active Exploration (marked by the number 3) into one called Guidance Balance. Figure 3.1 suggests they

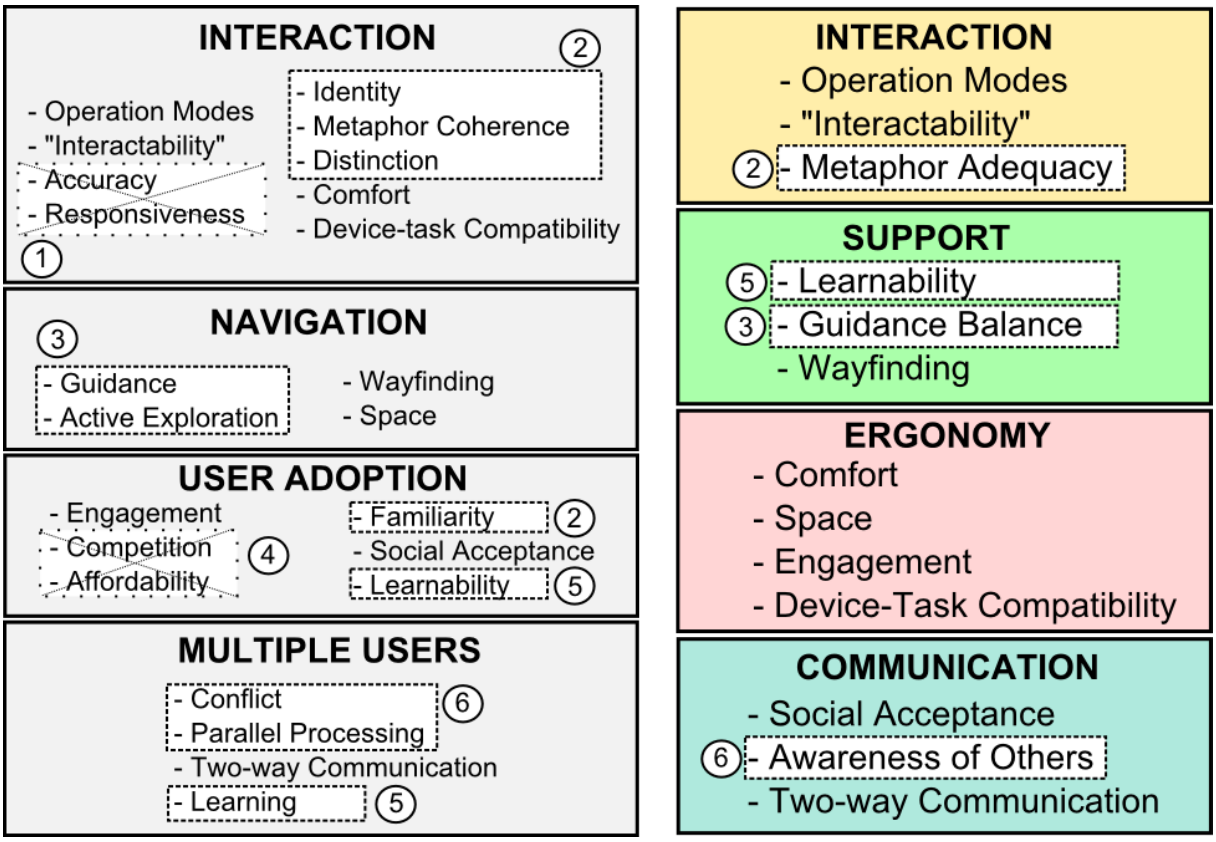


Figure 3.2: To the left, the original set of heuristics and, to the right, the new set of heuristics

both had similar scores, and the qualitative analysis reveals that both heuristics focus on the learning curve and on the balance between expert and novice users. The analysis of the HCI researchers for the Active Exploration heuristics even reads "as pointed in Guidance, there is free exploration of the system".

The number 4 in Figure 3.2 points to the exclusion of the two heuristics Affordability and Competition. Figure 3.1 shows some divergence in Affordability, but that was because of the different views the participants had on how affordable the system was. Furthermore, the qualitative data showed that these two heuristics pointed to problems related to costs, market and technology.

The number 5 in Figure 3.2 shows that the two heuristics Learnability and Learning were grouped as Learnability. Although originally one was meant for every type of system and the other was specific for interfaces with simultaneous multiple users, the way they were written was semantically very close. Furthermore, the quantitative and the qualitative data show that the users fully understood the heuristic.

Finally, number 6 indicates the grouping of two heuristics (Conflict and Parallel Processing) from the Multiple Users major group. Although we did not have experimental data about them, closer inspection reveals they were semantically close, becoming the heuristic Awareness of Others.

In summary, from the original set of 23 heuristics, based on the experimental quantitative and qualitative data regarding its use, a new set of 13 heuristics was generated. It is important to note that the changes made were either removing or grouping heuristics together; no new heuristics were added.

3.3.3 The Heuristics in Detail

This subsection presents the details of each one of the 13 NUI heuristics, within the following format: number, name, description and example of use. The descriptions were based on both the original description from Maike et al. [80] and on the analysis of the experimental data.

[NH1] Operation Modes. The system must provide different operation modes (visual, auditory, tactile, gestural, voice-based, etc.). In addition, the system must provide an explicit way for the user to switch between the modes, offering a smooth transition.

Example of Use: For the system tested in Experiments 1 and 2, the operation modes were: voice command (to run the application), pressing the smartwatch's physical button (also to run the application), dragging the screen (to close the application) and moving the arm to point the camera and frame someone's face. The evaluation for this heuristic pointed to problems related mostly to the transition between the modes. The experts concluded that the modes were competing with each other, since there was a delay to open the application, there was no sound feedback to inform the successful closing of the application, and the framing with the arm movement was difficult.

[NH2] "Interactability". In the system, the selectable and the "interactable" objects should be explicit and allow both their temporary and permanent selection.

Example of Use: In Experiments 1 and 2, participants pointed as "interactable" objects, the smartwatch's physical button, its camera and its screen. In Experiment 3, the HCI researchers said the people in front of the Kinect were the "interactable" objects.

[NH3] Metaphor Adequacy. The sets of interaction metaphors the system provides should make sense as a whole, so that it is possible to understand what the system can and cannot interpret. When applicable, there should be a visual grouping of semantic similar commands. In addition, the interaction metaphors should have a clear relationship with the functionalities they execute, requiring from the user a reduced mental load and providing a sense of familiarity. Finally, the metaphors should not be too similar to one another, to avoid confusion and facilitate recognition.

Example of Use: In Experiments 1 and 2, one of the interaction metaphors was the visual feedback the system provided while framing a person's face. When a face was detected, the system placed a rectangle around it and a voice said "framing". This audio clue did not translate completely the metaphor of the rectangle, which represents the focus functionality of a digital camera, which usually displays a rectangle in the screen to say that the image focus is being adjusted. Additionally, the evaluations also pointed that since the system is embedded in a smartwatch, a device that resembles a normal wristwatch, there is a natural sense of familiarity in using the system.

[NH4] Learnability. There has to be coherence between learning time and frequency of use. Therefore, if the task is performed frequently then it is acceptable to require some learning time; otherwise, the interface should be usable without much learning effort. In addition, the design must consider that users learn from each other by copying when they work together, so it is important to allow them to be aware of each other's actions and intentions.

Example of Use: In Experiment 1, the same person acted as a blind user more than once. This allowed us to measure the execution time of each iteration, and the results [31] showed that this time greatly decreased after the first round. Therefore, the system was easy to learn after a few minutes of use.

[NH5] Guidance Balance. There has to be a balance between exploration and guidance, to maintain a flow of interaction to both the expert and the novice users. To enhance transition from novice to expert usage, active exploration of the set of interaction metaphors should be encouraged by the system. Finally, it is important to provide shortcuts for the expert users.

Example of Use: The system tested in Experiments 1 and 2 provided both visual (rectangle around a face) and auditory guides (voice saying "framing", the name of the recognized person or "unknown"). In this sense, the user has freedom to explore freely, but to achieve her goal she will have to follow these feedbacks. In addition, the differentiation between novice and expert users is in how they interpret the feedbacks. For instance, it takes some time to understand that when the system says "framing" it is necessary to keep the arm still, so the system can finalize the recognition.

[NH6] Wayfinding. At any time, users should be able to know where they are from a big picture perspective and from a microscopic perception. This is important regardless of user proficiency with the system, i.e., novice and expert users need both views of the system.

Example of Use: In Experiments 1 and 2, the big picture perspective is the search for faces to scan, which also involves knowing how many people are in the environment and how big it is. The microscopic perception is the framing of one person's face, to find out who she is. In this sense, the feedbacks the system offers are more helpful to the microscopic perception than to the big picture.

[NH7] Comfort. Interacting with the system should not require much effort from the user and should not cause fatigue.

Example of Use: The system tested in Experiments 1 and 2, with the smartwatch, received several negative evaluations from the experts due to fatigue caused by keeping the arm raised for a long period. They noted, however, that there were the issues of lack of practice from the users and low compatibility between the experiment and the real use. In contrast, the system tested in Experiment 3, with the Kinect, did not present physical discomforts, neither from the helmet nor from the backpack.

[NH8] Space. The location where the system is expected to be used must be appropriate for the kinds of interactions it requires and for the number of simultaneous users it supports.

Example of Use: In Experiment 3, a problem that happened many times was that, when the blindfolded user came too close to someone (around 60 centimeters), the system would stop detecting that person. In this sense, to fully comply with the heuristic the system would have to emit a warning before the user left the ideal distance from the person (which is around 1,20 meters).

[NH9] Engagement. The system should provide immersion during the interaction, at the same time allowing for easy information acquiring and integration. Example of Use: For the system tested in Experiments 1 and 2, the task of framing people's faces and finding out who they are could be more fun once the fatigue issue is resolved.

[NH10] Device-Task Compatibility. The system has to offer kinds of interactions that are compatible with the task for which it is going to be used.

Example of Use: In Experiment 3, the task of using the Kinect for locating and recognizing people proved to be very compatible with this device, given the lack of comfort issues and satisfactory success rates. In literature, however, there are examples of bad task compatibility for the Kinect, such as those reported by Cox et al. [28] who used it as a mouse cursor to select objects in a screen. This way, the user had to keep the arm raised and control the cursor by moving the arm or the hand. In this case, compared to other devices the authors found the Kinect presented high fatigue, low efficiency and high error rates.

[NH11] Social Acceptance. Using the system should not cause embarrassment to the users.

Example of Use: For the system tested in Experiments 1 and 2, participants point-ed out that the smartwatch should not cause embarrassment because it is very similar to a regular wristwatch. In fact, they noted that, given its novelty and cost, it can be seen as a symbol of status.

[NH12] Awareness of Others. If the system supports multiple users working in the same task at the same time, then it should handle and prevent conflicting inputs. Therefore, users must be able to work in parallel without disturbing each other, but having awareness of the others.

Example of Use: Nebe et al. [94] present the multi-touch table they have built and how it is used in a scenario of disaster control management. In that case study, multiple users work simultaneously on a map displayed on the table. Each user can have their own tangible object (a puck) to interact with the map. Placing the puck on the map can zoom in, make markings on the map or create a personal window for the user on the screen, so each person can execute their own tasks in parallel without disturbing the group view of the map.

[NH13] Two-way Communication. If multiple users are working on different activities through the same interface, and are not necessarily in the same vicinity, the system must provide ways for both sides to communicate with each other.

Example of Use: Yang et al. [139] present a study in which participants used a multi-touch screen interface to collaborate remotely. In a ludic activity, one participant shared what she was doing in the multi-touch screen and a group of other participants, in a remote location, had to guess what was the task being executed. The participants in the remote location could not communicate back to the person performing the task, so one of the reported results was that participants wished they could do that through the system's interface.

3.4 Conclusions

Natural User Interfaces (NUIs) represent a strong tendency for new computer systems, as well as a challenge for designers, since delivering the promised feelings of naturalness is not trivial. In this paper, we showed three practical experiments using a set of 23 NUI heuristics as a tool for evaluating the design of two distinct assistive technology systems. During the experiments, participants also evaluated the heuristics themselves. Results of the experiments led to a leaner set of 13 NUI heuristics, with a compliance level ranging from -4 to 4.

This new set of heuristics is result of revisiting the previous set with both quantitative and qualitative analysis. Since two experiments tested the same system but with completely different groups of participants, we were able to look for divergences in the interpretations of the heuristics, so we could find the ones that needed to be rewritten or regrouped. This quantitative analysis was supported by the qualitative evaluation of the participants' justifications for their grades, which gave insight into how they understood each heuristic and, hence, what improvements were necessary.

Therefore, the experiments provided us both with the view of the heuristics in practice and with the opportunity to improve them. They also allowed us to enhance the description of each heuristic by providing an example of use taken straight from the experiments, whenever possible. Some heuristics were not applicable to the experiments, so we see as necessary future work applying the new set of heuristics in systems that support multiple users working simultaneously on the same interface. Additionally, we also believe further experiments and empirical uses of the heuristics will point to design principles that can be helpful in guiding designers in early stages of NUI applications design.

Chapter 4

Designing Natural User Interfaces Scenarios for All and for Some: an Analysis Informed by Organizational Semiotics Artifacts

4.1 Introduction

Known as Natural User Interfaces (NUIs), this interface paradigm in Human-Computer Interaction (HCI) encompasses devices and technologies that, as the term "natural" implies, only require users to do what comes naturally to them, instead of having to develop technical skills to be able to interact with the interface. This, as [100] argue, can both attract users who do not feel comfortable with the traditional mouse and keyboard interfaces, and elicit new design and engineering challenges that will inspire research in several different knowledge areas. However, to become actual usable products, these ideas need to consider, from the very beginning, the context in which the new technology will be used and who its potential stakeholders are. Organizational Semiotics (OS) provides tools with the potential for this analysis of organization and context, but given the novelty of NUIs there is the additional challenge derived from considerations of Accessibility and users with disabilities. Although there are some initiatives in this direction, be it in the form of general NUI guidelines [137] or in the form of design and evaluation heuristics for NUIs [80], creating new technologies with NUI that are both useful and usable by a vast diversity of users' capacities is still a challenge.

The work described and discussed in this paper is part of a research project that aims at exploring existing NUI devices and testing both their own Accessibility (i.e., its interactability by people with disabilities) and their usage in the context of facilitating everyday actions of people with disabilities. The latter implies in either employing these devices as they are or by altering them or combining them with other devices. This project has two main goals. The first is to propose a conceptual framework for the design of NUI devices that consider the context of Accessibility. The second objective is to design and engineer new devices that not only help people with disabilities, but also that meet the requirements of Universal Design (UD). Once we achieve these goals, products may help in the design of new NUIs that encompass as many users as possible. Therefore, we aim at designing NUI-based technologies with potential of being more inclusive for people with disabilities and more interesting and useful for people without disabilities. We believe that Organizational Semiotics (OS) can help to achieve these goals by providing a contextualized view of the problem we are dealing with. In this work we use the OS artifacts to clarify and represent our research project, showing how they allow pointing either in the direction of UD or of Assistive Technologies (AT). On one hand, UD means creating products that are usable by anyone, regardless of features such as age, culture, language or disability [136]. In Computing, there is a related term, "Universal Access", which refers to ensuring that all people have access to technology and information, and that these computing services are usable by anyone [118]. Although UD might seem very hard or even impossible to achieve, it should at least inspire designers to create better solutions [5]. Therefore, we believe UD is a design goal that should guide the design process from the very beginning of a computing project. On the other hand, AT refers to devices or computing systems created to compensate, relieve or neutralize body impairments [52]. This encompasses assisting people with disabilities in the execution of tasks and, in turn, improving their social participation and autonomy. Despite their potential benefits, ATs commonly suffer from abandonment by their users, usually because of difficulties related to adapting to the AT or in learning how to use it. To overcome these problems, it is important to involve the stakeholders in the design process, especially those closest to the users, such as family, friends, caretakers, doctors and nurses [52].

Looking at the two concepts of UD and AT it is possible to see they contrast in how they treat their target users: while UD tries to tend to as many users as possible, ATs focus on helping specific users perform specific tasks. However, they have in common the fact that they both need a deeper consideration of context and both can benefit from SO artifacts. In this paper, we will show how different uses of the artifacts can best promote either AT or UD.

The paper is organized as follows: In Section 4.2 we give an overview of the theory behind the OS methodology we employed. Then, in Section 4.3 we present the OS artifacts and the practical scenarios instantiated from them. Section 4.4 discusses how the different problem-solving approaches taken in each scenario reflect on the SO artifacts and, ultimately, in the final solution. Finally, Section 4.5 presents our concluding remarks and overview of future work.

4.2 Theoretical Basis

The Organizational Semiotics (OS) proposes a comprehensive study of organizations in different levels of abstraction (informal, formal and technical), and their interdependencies. For OS, organizations can themselves be information systems with norms and patterns of well-defined behaviors that regulate the internal processes within the organization. In this sense, an organization is composed of three layers [71]: informal (outer layer), formal (middle layer), and technical (inner layer). The premise behind the use of OS in information systems is understanding the situated context of the organization that the system will be inserted in, and clarifying the main forces that act on it, to propose a technical information system that makes sense for these organizations. Understanding organizational functions from the social level is essential for achieving this goal [71]. To enable a better understanding, development, management and use of information systems, a set of methods known as MEASUR (Methods for Eliciting, Analyzing and Specifying User's Requirements) was developed in the OS [123]. In this paper, we make use of some of these methods aiming at clarifying the problem and proposing solutions, which can have an impact on the design of both Universal Design and Assistive Technologies. For this, we use three artefacts, two of which are from the OS: the Stakeholders Identification Diagram (SID) and the Semiotic Framework (SF). The third one is the Evaluation Frame (EF), used to discuss problems the stakeholders may find and anticipate solutions to them [15]. We briefly describe them as follows, and in the next sections, we discuss their instantiations in our research project.

The SID [72] facilitates the identification of those involved in a particular design process. SID pays attention to different levels of involvement, interests, and expectations, allowing the visualization of stakeholders and their organizations inside five different categories: Operation, Contribution, Source, Market, and Community. In turn, the EF is intended to support reasoning about problems and solutions related to each stakeholder identified through the SID. Therefore, it favors the clarification and identification of requirements as well as the anticipation of issues that may impact/influence the solution to be designed. EF is represented in a table format where the columns contain problems and solutions, and each line references one of the five SID categories. The idea is to raise, in each of these layers, the identified problems and solutions for each group of stakeholders.

Finally, the SF [123] favors the identification and organization of requirements according to six different levels that represent different aspects of signs. The first three levels can be related to technological issues (the Physical, Empirical, and Syntactic), and the other three levels can be related to aspects of human information functions (Semantic, Pragmatic and Social World). The Physical World indicates the features and signs that can be measured by physical analysis and engineering. Empiric studies the properties of the signs. Syntactic analyzes the relationship between signs (whether formal or structural). Semantic describes the relationship between a sign and their meanings. Pragmatics studies the relationship between a sign and the behavior of the involved agents. Finally, the Social World evokes the need to understand how the rules of interactions between the groups work. The SID and EF were used to clarify the scenarios in which we experienced NUI technologies, while the SF supported the organization and specification of requirements and design decisions to be made. Therefore, these three artifacts contributed with a perception of the problem domain and its possible solutions.

4.3 The Instantiated Artifacts and Case Studies

Although the term Natural User Interface (NUI) has gained power after the advent of innovative devices [100] such as the Microsoft® Kinect [1], NUI-based devices can be created using any kind of input modality, as long as the experience feels natural and the technology best reflects the abilities of its users [137]. This means that it is possible to create a Natural User Interface with a combination of older technologies (like mouse and keyboard) with newer ones (like gestural or touch), because the potential for naturalness is in those technologies, but not the guarantee of it. This trade-off between potential and guarantee creates excellent design and research opportunities, since the possible combinations of input and output devices for the creation of new NUIs are countless. However, it also elevates the challenges behind the task, since employing a technology that is recognizably in the NUI paradigm does not give certainty that the resulting device will actually provide a natural experience for the user. Part of the challenge also lies in understanding the NUI-based devices' potential for users and their context of use. This means taking into account different user needs, based on the characteristics of the users themselves and on where they would utilize the technology. In our research project, we look at this problem from the perspective of people with disabilities. We want to investigate how NUIs can help these users in several ways, such as in accomplishing daily tasks, gaining autonomy, being included in society and interacting with other people.

The first step to understand the problem is to look at the stakeholders of the NUI technologies and devices we aim to explore and design. This is where the SID comes in. In the inner layer, Operation, we have the users of the NUI devices, and, as we move to the outer layers, we define other stakeholders such as researchers and developers (Contribution) the users' families and friends (Source and Community), technology companies (Source and Market), Government and society (Community). In the EF, this brings out questions like "How does the device affect user's interactions and relationships with friends and family?" or "How does Government regulation adapt to the new devices?". Furthermore, although we guide our project with the principles of Universal Design [136], we are also trying to understand how to better design NUI-based devices for people with disabilities. Therefore, some of our stakeholders are specific to this audience, such as the industry of accessibility materials and associations for people with disabilities. In our EF, this leads to questions like "How do the associations for people with disabilities benefit from the devices and technologies created?", which we answer as "they have early access to prototypes and, later, can use the finished final products". Therefore, the SID and the EF give us a contextualized view of our research problem, helping us anticipate problems and solutions related to each stakeholder. To explore the artifacts even further, we have created from them three different case studies. The following subsections describe these case studies and explain how they contribute to our research problem.

4.3.1 Microsoft® Kinect and the Visually Impaired

In the first case study, we started from two stakeholders in our SID: "people with disabilities" from the Operation layer, and "technology companies" from the Source layer. We instantiated each as "people with visual impairments" and "Microsoft", or more specifically, its NUI device, the Kinect [1]. From there, we focused on the challenge of using the Kinect to help visually impaired people (i.e., the blind or people with low vision) in their daily tasks, such as navigation and recognizing objects, informative signs and people. The Kinect is a device composed of 3D depth sensors, an RGB camera and a microphone. Therefore, the main goal of this study case is to figure out how to translate the visual information input given by the Kinect into an output the target users can easily understand. For this, we chose 3D audio because of its capability of carrying an information, such as the location of an object in relation to the user, in an indirect way. To test the applicability of this solution, we built a prototype, uniting the Kinect, bone conduction headphones and algorithms of Computer Vision (to interpret the visual input) and 3D Audio (to generate the auditory output). This prototype allowed us to conduct laboratory experiments with users and figure out technical, ergonomic and usability issues. Since until now we only have conducted experiments in controlled environments, so far we have tried to answer questions from the Operation and Contribution layers of the EF, such as "How efficient is the operation?", "How comfortable does the user feel using the device?" and "How does the user benefit from the device?". Once the experiments reach real-world tests, we will also be able to get feedback on the questions and problems presented in the other layers, like "How can friends and family help the user to configure or learn how to use the device?", taken from the Source layer. Therefore, the main contributions of this case study to our research problem are the insights into the building process of a NUI-based device, especially when the starting point is an already existing NUI technology that needs to be adapted. Additionally, we will also continue to see how the analysis we made with the SID and the EF applies in this instantiation of our research problem.

4.3.2 Samsung® Galaxy Gear and the Visually Impaired

In the second case study, we again started from two stakeholders in our SID: "people with disabilities" from the Operation layer, and "technology companies" from the Source layer. We instantiated each as "people with visual impairments" and "Samsung", or more specifically, one of its NUI devices, the first generation Galaxy Gear [7]. From there, we focused on the challenge of using this device to help visually impaired people with the task of recognizing people in their surroundings. The Galaxy Gear is a smart wristwatch (or smartwatch) that has an 800 MHz processor, 512MB RAM, 4GB of internal memory, 2 microphones, a speaker, Bluetooth capabilities and a 1.9 Megapixel camera on the wristband. It can also communicate with the user's smartphone to execute tasks such as answering calls and reading messages. Therefore, the main goal of this case study is to figure out whether and how a wearable device such as the smartwatch can help the visually impaired with the task of recognizing people around them. This involves not only developing Computer Vision algorithms that are able to run on a device with limited hardware capabilities, but also figuring out the best ways to provide feedback to users in ways they can easily understand. Additionally, the feedback cannot overwhelm or embarrass the user. We have conducted experiments with users within laboratory conditions and found issues related to software, ergonomics and feedback. Therefore, similar to the first case study we have so far tried to answer questions from the Operation and Contribution layers of our EF. Once we carry on to real-world tests, we will be able to answer questions from the other layers, such as "How does the device affect interactions or relationships between the users and their families or friends?" (taken from the Source layer), or "How does the new device impact on NUI devices companies?" (taken from the Market layer). Additionally, in this case study we are again exploring a NUI technology (smartwatch) within the context of a specific group of users (the visually impaired); however, in this scenario we are not adapting the device on the hardware level so far, but on the software level. Therefore, the main contributions of this case study to our research problem are the insights into adapting, on the software level, a NUI wearable device to perform tasks it did not originally fulfill (recognizing people with the camera). Furthermore, we are also able to see how the analysis made with our SID and EF will continue to apply in a concrete instantiation of our research.

4.3.3 Web of Things in the Supermarket

In the third and last case study, we started from several stakeholders in our SID: "people with disabilities" and "other users" (Operation and Contribution), "technology companies" (Source), "NUI devices companies" (Market), "interested society" (Community) and "Academia" (Community). Their instantiations would be, on one hand, any person interested in receiving help with the task of selecting and finding items in a supermarket ("people with disabilities", "other users" and "interested society"); on the other hand, we have those involved in the area of the Web of Things [143] ("technology companies", "NUI devices companies" and "Academia"). Then, we focused on the challenge of using the Web of Things concepts to help any kind of customer to find and select items in a supermarket.

The Web of Things (WoT) is a research field derived from another field called Internet of Things (IoT). On one hand, the IoT is concerned with the transition of the Internet from a network of computers to a network of trillions of smart "things", such as mobile devices, home appliances and sensors. On the other hand, the WoT revolves around reusing and adapting technologies and protocols that exist in the current Web to build applications that will run in the IoT. Hence, this case study has the goal of using the network of sensors, smartphones and other "things" that may exist into the supermarket to help people in the tasks of finding and choosing products in the establishment. Additionally, the case study also encompasses providing ways to use the WoT to, direct or indirectly, make users help each other. This means providing functionalities that will allow, for instance, people without disabilities to give information that may help people with disabilities, such as product reviews and translation or transcription of information presented on the packing. Notice that this can also be useful to other types of users, such as foreigners, elderly and people who are uncertain about the quality of a product.

After coming up with the general idea of the case study, we looked at the possible technologies that could be used to create the device we are aiming at. We decided an RFID (Radio-Frequency IDentification) reader, some RFID tags and a text-to-speech software were enough for a first experiment. Despite the controlled conditions of our simulated supermarket, we discovered important issues related to the sound feedback, especially regarding the semantics and the syntactic structure of the information given to the user. More specifically, several users could not comprehend the directions to find the sections of the supermarket, and others had trouble understanding reviews of products left by other users. These issues are direct reflections of questions from our EF, such as "How efficient is the operation?" (Operation layer) and "How do users report problems?" (Contribution). Once we move on our experiments to non-controlled environments, we will be able to answer questions from other layers, like "How do supermarkets benefit from the device?" (Market layer) and "How can academia benefit from the device?" (Community layer). Therefore, the main contributions of this case study to our research problem are the insights into creating a device that, from the start, is aimed at any user and that helps people with disabilities. Additionally, also gain perspective on how our analysis made with the SID and the EF work on this instantiation of our research problem.

4.4 Results and Discussion

Each of the case studies described in the previous section was informed by analysis on the same SID and EF. However, while the first two scenarios adopted the approach of starting the design from an existing NUI technology, the third one started from the problem and looked for technological solutions to it. These two different approaches (and their consequences) can be evidenced in the Semiotic Framework (Fig. 4.1)

If we think about the organizational onion [71], the first two case studies have taken the direction that goes from the technical layer to the informal layer, while the third case study started in the informal layer and went to the technical layer. Looking at this in the SF, the first two case studies started in the most bottom step, the Physical World, by defining the technologies they would use in their designs (Kinect or smartwatch) and moved to the top step, the Social World. In turn, the third case study went the opposite way, by defining the problem and the concern for Universal Design in the top step, and then moving down to reach the Physical World. Hence, from now on in this text we will refer to the first approach as "bottom-up" and to the second as "top-down".

If we make a more detailed analysis, we can see the impact each approach has in each level of the SF (Figure 4.1). The bottom-up approach starts in the Physical World by choosing a NUI device and combining it with the necessary auxiliary technologies, such as white cane for the blind user, headphones to receive audio output and, lastly, the multichannel communication needs to be considered. In the case of the Kinect, hardware and software modifications were made to implement one of the channels: the audio. In the case of the smartwatch, only software adaptations were necessary since the device's hardware already has multichannel capabilities. Moving on to the Empiric layer, the efficiency of the audio feedback is tested and adjusted, usually by software. Then, in the Syntactic layer, the pattern and format of the feedback are defined and possibly require more adjustments. In the Semantic step, we consider how much the audio cues are understandable to the users, and possibly make more adjustments. In the Pragmatic layer, we see how much the device as a whole is actually helping the user in the execution of a task. Finally, in the Social World step we consider issues related to embarrassment and segregation.

In contrast, the top-down approach starts by defining the problem (finding and selecting products on a supermarket) and committing to Universal Design, i.e., helping as

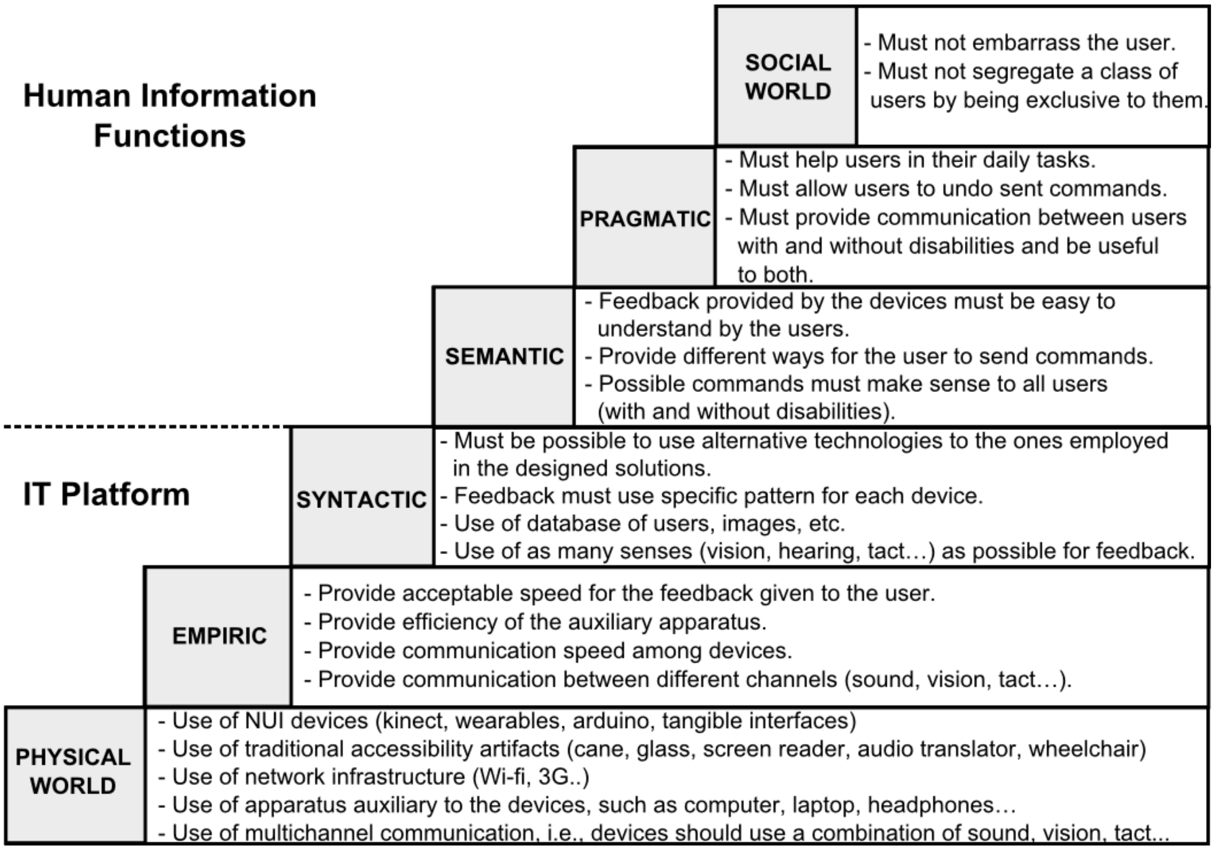


Figure 4.1: Requirements represented in the Semiotic Framework (SF).

many types of users as possible in the accomplishment of the chosen tasks. Moving to the Pragmatic layer, we think about how to provide communications between users, and how to make these communications useful for them and compatible with the proposed problem. Then, in the Semantic step, we design the input (commands) and output (feedback) messages so that they are understandable by as many users as possible. In the Syntactic layer this reflects upon the format we will choose for the messages, the types of senses (vision, tact, hearing. . .) we will choose to reach and which databases we will use. This also carries on to the Empiric layer, where we consider which communication channels to use and how efficient each one is. Finally, in the Physical World we actually select the devices that will be used and combine them to achieve a prototype of the solution.

Therefore, it is possible to note that, on one hand, the bottom-up approach requires software and hardware implementation from the very start, and for each step we move up on the SF, adjustments are required, which can be very costly both for designers (time and labor) and users (time). Additionally, the bottom-up approach also offers less flexibility in terms of the technologies employed, since they are chosen very early. This also implicates that once we reach the Social World it may be very difficult to adapt the current physical apparatus to fit all. On the other hand, the top-down approach only commits to specific physical devices in the very last step, allowing designers to consider UD-related issues much earlier. This gives them freedom to select the NUI devices and technologies that best fit the requirements they came up with during the descent from the Social World to the Empiric layer. This can save both time and money, since it will be possible to compare, in the Physical World, the different options that satisfy the requirements and then select the one that costs the least. We believe that these crucial differences in the two approaches point to the contrast between designing an Assistive Technology (AT) and designing a solution that follows Universal Design (UD). While AT usually refers to a device or computing system that assists people with disabilities [52], UD defends the creation of products that are usable by the greatest possible extend of categories of users [136]. Hence, the SF indicates that, in the context of designing new NUI-based devices with a special attention to users with disabilities, the bottom-up approach may lead to an Assistive Technology that will most likely to address a specific category of user. In contrast, the top-down approach seems to promote Universal Design solutions. It is important to note, however, that within an iterative design process, it is possible to adapt the designs so they can address a wider variety of users, but this adaptation seems to be much more difficult if we are adopting the bottom-up approach.

4.5 Conclusions and Future Work

In this paper, we used the lens of Organizational Semiotics on a research project that aims at exploring the existing NUI-based devices in the context of Accessibility, either by testing their potential as assistive technology or by investigating how they can allow everyday actions of people with disabilities and others as well. The ultimate goals of this project are creating new NUI-based devices and proposing guidelines or conceptual frameworks for designing these devices in the future.

The results of this study showed the usefulness of the Stakeholders Diagram and the Evaluation Frame to guide the creation of three different case studies scenarios and, in return, how the discoveries made in each case study reflected differently in the artifacts. In addition, we observed that the different directions of designing the scenarios reflected in the organization of requirements in the Semiotic Ladder. Finally, we observed evidence that starting a design from the top or from the bottom steps of the Semiotic Framework can have a huge impact on the way the resulting technology will address the user, either leading to an assistive technology or a solution for all, aligned to the principles of Universal Design.

We believe this evidence illustrates the contribution of Organizational Semiotics artifacts towards a design for all, especially in the context of using NUI state of the art devices. Hence, our future work includes proceeding with further iterations of each case study scenario to understand other semiotic aspects of those technologies in their real world usage.

Chapter 5

A Smart Supermarket must be for All: a Case Study Including the Visually Impaired

5.1 Introduction

In the year 2000, Hall [53] envisioned a smart city as a safe, efficient and environmentally green urban center, made possible by the use of integrated materials, sensors, electronics and networks. The main idea is that such city can optimize its resources, monitor security aspects and provide better services to its citizens. More than ten years later, Nam & Pardo [93] collected all the synonyms for "smart city" used in literature and characterized the term as the intersection of three dimensions: technological, institutional and human. The first refers to the computing infrastructure that is necessary to transform life and work in a city. Institutional refers to policy and regulations necessary to make it all possible. Lastly, human factors is about the intellectual and social capital indispensable to build a smart city. It refers also to social inclusion and accessibility smart cities might bring.

In sight of the presented concepts, in this paper, we focus on both the technology and the human aspects of smart cities. More specifically, we chose a particular scenario – a supermarket – to explore how smart technologies can help any person (in particular, those with visual disabilities) to find and select products. We also empower people to help each other by leaving comments about products in the supermarket, as if in e-commerce stores, but in this case, the comments are associated to the physical objects of the store.

Regarding technology, we share the vision of Lea & Blackstock [67] that the Internet of Things (IoT) paradigm can be a platform for smart cities. IoT may be defined as the enhancement of everyday objects by electronic devices, making them intelligent and connected to the Internet [64]. Moreover, IoT refers to this network of smart objects, the technology necessary to support it, and the set of applications and services that drive them to create business opportunities [89]. An easy and low-cost way to make an object smart is by using RFID (Radio Frequency Identification) technology. This is a common alternative to barcodes for identifying objects [64], since there is no need for a careful positioning between the barcode and its reader. The electronic tags, called RFID tags, store the unique identifier of an object, and an RFID reader can scan the tags from a small distance, not requiring much precision. This simplicity supports the tracking of physical objects within well-defined spaces, but it can be a challenge to deploy a network of RIFD tags and readers [65]. However, it is possible to create an IoT with RFID, as Welbourne et al. [135] have succeeded in doing so, and in creating web-based tools that allowed users to manage their smart objects.

For the human dimension, we focus on two pillars. The first is Universal Design (UD), i.e. "creating environments and products that are usable by all people to the greatest extent possible." [74]. Hence, we see the pervasiveness of smart cities as a two-way street: at the same time that it reaches and monitors people, it should be accessed by anyone, regardless of culture, age, gender, disability or any other characteristic. Our second pillar are Natural User Interfaces (NUIs). Popularized by Ballmer in 2010 [12], this term refers to ways of interaction that go beyond the mouse and keyboard, such as gestural, voice-based, touch and tangible, for instance. However, we agree with O'Hara et al. [100] that the feelings of "naturalness" provided by a system are more important than the technologies employed. In this sense, the ubiquitous nature of the IoT joined with the easy-of-use of RFID technology, constitute a NUI with a seamless interface.

Bearing in mind the explained aspects of technology and human factors, in this paper we present a system that implements the Internet of Things, using RFID, within the scenario of an inclusive supermarket. It is an embedded solution of the Universal Navigation Exploration and eXchange with Things (U-NEXT) system, which supports people while they explore, for instance, a supermarket and its products. We evaluated the system in two experimental scenarios. The first was with students from a graduate discipline, and the other was with visually impaired users. Our aim was to explore this scenario to understand real technical and usage problems that impact different audiences and also on the system environment as a whole.

The paper is organized as follows: The next section introduces the U-NEXT System architecture and its instantiation. Then, we present our case study followed by discussion of main findings. The paper concludes with considerations and directions for future research.

5.2 The U-Next System Architecture

Universal Navigation, Exploration and eXchange with Things (U-NEXT) is a pervasive system that uses Internet of Things services to promote interaction and exchange of information among people, objects and smart devices. It seeks to promote direct and indirect collaboration between users, devices and environment [82]. As it was conceived, this system architecture is meant to adapt to several contexts and scenarios, but this research focuses on Accessibility and Universal Design issues. As premises, the system seeks to explore the smartness of "things" involved in the IoT to:

- Promote utility services to, directly or indirectly, benefit people with and without disabilities.

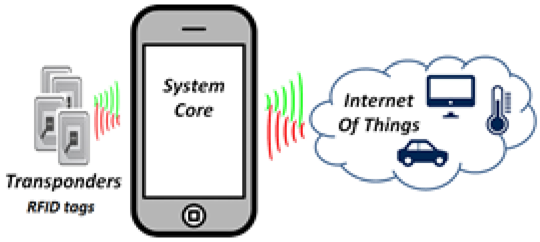


Figure 5.1: The high-level system architecture.

- Be portable so that other devices can connect to it to exchange information or services.
- Allow any user to help other users, with or without disabilities, serving a wide variety of needs.

In its initial idea, the U-NEXT System was designed with a laptop-based core connected with a USB RFID (Radio Frequency Identification) reader and RFID tags that acted as devices in an Internet of Things scenario [82]. The system core (our authorship) identifies codes (IDs) from RFID tags and identifies text messages associated with those IDs, converting them to a synthesized voice, which in turn the user hears. The system core also works as a gateway component between the world of RFID tags and the Internet.

Initial tests with the U-NEXT system, in its preliminary stage [82, 131] has shown that the technology used could be directed to a more autonomous and flexible solution. In this article, we introduce the concept of enhanced mobility for the system user. The idea is to embed the system core in mobile devices with RFID readers. Our main interest is to provide more comfort and quality of use, based on the improvements identified in previous versions of the system.

The embedded solution driven for mobile devices has brought new design challenges, in terms of both the user interaction and the hardware and software limitations. This solution could be used on any type of mobile operating system (e.g., Windows Phone and iOS), but for economic reasons we chose the Android operating system. Because of technical and project constraints, we chose devices that already have the RFID embedded in the system. Figure 5.1 shows the concept of the mobile system.

In the mobile version, the system was developed in Java ME, while in its prototyped laptop version it was developed in Python. The internal architecture of the mobile device must allow the system core to explore operating system resources (e.g., OS events), voice synthesizer system and the interface from the RFID reader. As a design requirement, the system must have a user-friendly interface that considers different users with different skills.

In this study, we instantiate the proposed system architecture (Laptop-Based or Mobile-Based) in a smart supermarket simulated environment. We chose this scenario because it presents many challenges for any user, regardless of having a disability or not. We imagined the scenario as a real supermarket, with gondolas, shelves and corridors. The difference is that in front of each product, on the edge of the shelf, there are two RFID tags: one with basic product information (name, brand, price and weight) and the other with opinions on that product left by other customers. The RFID tags were covered with

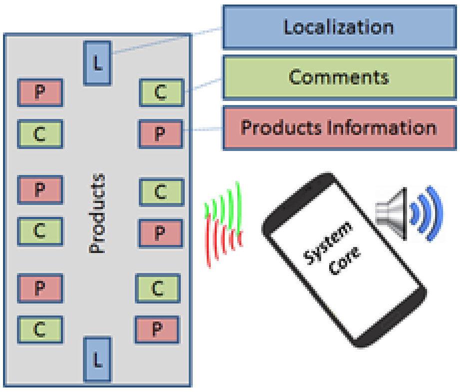


Figure 5.2: Example of our smart supermarket gondola.

paper labels. The label in the product information tag had written in it almost the same information (name, brand and price). The opinions tag had just a visual icon indicating it contained opinions in audio. For the customer navigation, the shelves also had RFID tags indicating the categories of each corridor. These tags were also covered with paper labels that only contained an icon to indicate the audio information. In addition, each corridor had large paper signs naming the kind of product located there. Figure 5.2 has an example of our smart supermarket gondola.

In this work, we have instantiated this smart supermarket in experimental scenarios, described in the next section.

5.3 Case Study

5.3.1 Scenario and Participants

A case study was conducted in a non-profit institution called "Pró-Visão", located in the city of Campinas. The main goal of this organization is the social inclusion of visually impaired people. To achieve this goal, they work with people of all ages, with varying degrees of visual disabilities (i.e. from low vision to complete blindness), and help them to gain autonomy in their day-to-day activities in the society. The institution offers them Braille courses, how to use the white cane, and to develop other skills. It operates as complements from schools to give support for students and their families as well. Several additional activities are offered for the participants such as crafts, sports and recreation, reading, literacy and information technology. A multidisciplinary team of educators, teachers, psychologists and other professional, supports students. Pró-Visão opened its doors to our group and other researchers to the investigation of new techniques e technologies that could be useful to their students in their daily lives, and to its staff. The people (minors and adults) who participated in our studies were indicated by Pró-Visão's staff.

This case study reports and discusses activities organized into two "workshops": the first, a pilot experiment, and the second, a formal experiment.

5.3.2 First Workshop: Pilot Experiment

The objective of this workshop was to allow users with visual impairments to interact with the U-NEXT system (still in the laptop) and explore the supermarket using the system.

We had three participants, all minors accompanied by family members or caretakers. There was one blind teenage boy and two low-vision teenagers, one male and one female. Both had different degrees of low vision. All participants had to accomplish a task: to explore the whole supermarket and choose one item to buy. Hence, the main objective of this workshop was to explore the system for the first time with users with actual visual impairments, serving as a rehearsal for the actual experiment.

5.3.3 Second Workshop: Formal Experiment

The objective of this workshop was to conduct an experiment with users with visual impairments, gathering qualitative and quantitative data from their use of the mobile version of the U-NEXT system.

This workshop had seven participants: two blind adult females, four adults with different degrees of low vision, and a girl with low vision.

Each participant had two goals in this activity. The first was to find and select three items from a shopping list. The second was to leave a comment about one product. They would simply need to speak and the system would use voice recognition to transform their speech into text and store it. Therefore, the main objective of this workshop was to explore the system in a task-oriented manner, so we could compare its usage data with previous experiments. These workshops followed a specific format and were part of the method we adopted in the study.

5.3.4 Method

As explained in the previous section, the U-NEXT system started as a prototype in a laptop and later became mobile. To support this transition, we organized two workshops: the first represented an exploratory scenario with the laptop prototype, and the second referred to an experiment with the mobile system.

Despite having different objectives (first workshop: exploratory; second workshop: task-oriented), both workshops followed a same format:

1. **Greetings.** Participants and researchers briefly introduce themselves (e.g. they say theirs names or educational backgrounds) when in a first meeting or just greet themselves). It is a moment to break the ice and begin to form bonds of trust. Additionally, it is also an opportunity to know more about their life histories, the abilities and levels of disabilities of each participant, and their ways of doing daily activities, etc.

2. **Signing consent.** This research project has the approval of an ethics committee and, therefore, every participant (or a person legally responsible for the minors) needed to sign a term of consent, saying they are aware of and agree with the research purposes. For people with visual disabilities, we present the option of

using a screen reader to listen to the term. For practical reasons, all participants agreed on having a researcher read the term aloud. Besides the signed consent, it is important to note that at all times there was the support from a psychologist or a social worker from Pró-Visão. This person also helped the participants to sign the term, using a ruler and their standard protocol.

3. **Preliminary conversation.** Researchers and participants engage in a small talk to make everyone comfortable with the subject and with each other's presence, asking questions related to the problem at hand, for example, talking about the way participants shop in a supermarket. This is important to gain insights of the real user's perspective on the problem before presenting them with the proposed activities through the system. Results of this conversation also provide essential qualitative data regarding the subject under study.

4. **System Introduction.** Researchers present the system showing the use of the devices that are under test conditions (e.g., RFID reader and transponders). This is important for participants to become familiar with the system and minimize anxiety of participating in the activity.

5. **Experimentation.** The researchers explain the task the participants will perform: shopping in a physical setting that simulates a supermarket. Then, one by one, the participants execute the task, allowing researchers to gather quantitative data, such as execution time, how many times the device was used, how they are used, etc. Some measures are usually logged by the system, other data are registered by the researchers.

6. **Individual Feedback.** After executing the task and interacting with the system, each participant individually responds a questionnaire about their individual experience. For instance, in the second workshop we used an adapted (tangible) form of the Self-Assessment Manikin (SAM) [20], which gave us quantitative parameters for the participants' feelings of valence, arousal and dominance. In the first workshop this phase was suppressed and the individual feedback occurred at the next step (Debriefing).

7. **Debriefing.** After every participant has gone through the previous phases, researchers and participants collectively discuss the experience. Participants, then, provide their qualitative feedback on the system usage by either pointing out the system strengths and weaknesses, or by giving suggestions of improvements or addressing new requirements. Participants also point out other similar systems or experiences they had or would like to have.

5.4 Results and Discussion

In terms of quantitative results, the first workshop provided us only with a baseline for comparison with other experiments, due to it being a pilot. This means we cannot use this data for statistical analysis, but we can make some inferences. In terms of qualitative data, the two workshops were very rich.

The experimental conditions of the second workshop allowed us to compare its quantitative data with an experiment we had conducted previously. In this case, the participants were graduate students from a 1-semester Human Factors course of the State University of Campinas (UNICAMP), in 2014. The original experiment followed the between-group design, meaning we separated the participants in three distinct groups and each group experienced different conditions. Group A represented the traditional way of shopping and had no system to interact with the supermarket. Group B had access to the U-NEXT system to interact with the supermarket, and no restrictions. Finally, Group C also had access to the system, but was blindfolded (simulating blindness). Hence, Group C was a rehearsal for the experiment with visually impaired users.

The null hypothesis of this experiment was the following: **H0:** *There is no difference, in terms of execution time and user feelings of valence, arousal and dominance, between using or not using a system connected to the Internet of Things to perform the tasks of finding and selecting products in a supermarket.*

Hence, our alternative hypothesis (**H1**) would be the opposite, i.e. "there *is* difference...".

We were able to reject the null hypothesis in terms of execution time and feelings of motivation, but not in terms of feelings of control and satisfaction [131].

In the second workshop, we are working with the same hypothesis, and the same experimental setup. Therefore, we can treat them as a fourth group in the between group experiment design (which we will call **Group D**), and make statistical analysis with the quantitative data from the four groups.

Hence, in the following subsections we show, discuss and compare both quantitative and qualitative data from the two workshops and from the original experiment. The quantitative data is organized in terms of execution time, feelings of satisfaction, motivation and control, and, finally, in amount of tasks execution.

5.4.1 Execution Time

In both workshops (and in the experiment with the graduate students), we measured how much time each user took to execute their main task. This way, the clock started counting when they entered the supermarket (always through the same place), and stopped when the users signalized they had finished shopping.

Table 5.1: Execution times (in seconds) in the first workshop.

Blind Boy	**Low-Vision Boy**	**Low-Vision Girl**
493s	231s	320s

Table 5.1 shows the results of the first workshop. The blind boy took the longest time, 8 minutes and 13 seconds (or 493 seconds). The teenage boy with low vision was the fastest, with 3 minutes and 51 seconds (or 231 seconds).

Table 5.2 shows the results from the experiment with the graduate students (first three columns) and the results from the second workshop (last column). Each line represents a different participant, and the last line, in bold, shows the average time for each group. Since the second workshop had two blind participants, their results have a (B) next to them.

Table 5.2: Execution times (in seconds) for Groups A-D.

A [no system, no blindfold]	**B** [system, no blindfold]	**C** [blindfold, system]	**D** [system, disabilities]
71,82	207,19	422,85	712
124,78	251,4	421,12	509
147,55	259,14	328,72	492 (**B**)
81,91	208,94	418,66	389
83,77	271,13	782,96	427
107,91	211,15	352,35	458
	238,37		231 (**B**)
Avg: 103	**235**	**454**	**460**

The first aspect that is interesting to note is that the execution time of the first blind from Group D is almost identical to the blind boy's time in Table 5.1. This could be an indication of the approximate time a blind person would take to explore the simulated supermarket and execute the tasks of finding and selecting products. It is also consistent with the average time of the participants from Group C (blindfolded people).

Another aspect that calls attention is that the second blind person from Group D was the fastest of the group, beating those that have low vision. The reason for this seems to be that the last blind participant was (according to her own testimony) anxious about the experiment, so she sped through the activity to finish it quickly, barely exploring the supermarket. This looked like a positive aspect of the system.

It is also possible to see that the averages from groups C and D are very close from each other and rather close to the blind boy's time in Table 5.1. This could indicate that there is no difference, in terms of execution time, between blindfolded and visually impaired users. In turn, this means that, for purposes of experimentation and quantitative analysis, in the early stages of system development there are advantages in simulating a disability.

Finally, we can also see that the average time from Group B (people without disabilities that used the system) is very close to the times of the two low-vision teenagers from the first workshop (Table 5.1). However, their times are lower than Group D participants who also have low vision. This may be interpreted by the differences in the workshops' tasks. For low vision users, the time to explore the supermarket ranges from 231 to 320 seconds, and the remaining difference of up to 458 seconds is the time it takes them to find the three items of the shopping list, choose from the available options of brand and, finally, comment about any product.

Because this was a between-group experiment with one independent variable and more than two conditions, according to Lazar [66] we can apply the One-Way ANOVA to analyze the data in Table 5.2 (except for the last line, with the averages). This analysis returned **F=15.6** and **P=0.00001**, which means we can reject the null hypothesis in terms of execution time. Hence, we can conclude that there is a significant difference between using or not using a system connected to the Internet of Things, in the tasks of finding and selecting products in a supermarket.

5.4.2 Satisfaction, Motivation and Control

In the first workshop, there was no time for the participants to complete the SAM questionnaire, so for this subsection we only have the data from the second workshop and the experiment with the graduate students. We asked all groups to evaluate how they felt about the activity. Group A evaluated the experience of shopping in the simulated supermarket without the system, and the other groups evaluated the experience with the system.

Table 5.3 shows the ratings for the Valence parameter, in which lower values indicate greater feelings of satisfaction and pleasure. The last line, in bold, shows the mode for each column. Just like in the previous subsection, each line represents a different participant.

Table 5.3: Levels of Valence from the SAM questionnaire.

A [no system, no blindfold]	**B** [system, no blindfold]	**C** [blindfold, system]	**D** [system, disabilities]
3	3	1	1
4	1	3	3
5	1	3	5 (**B**)
7	1	2	1
3	1	6	3
1	4	1	1
	1		3 (**B**)
Mode: 3	**1**	**1;3**	**1;3**

For Group A, it is evident that the grades fluctuate around neutral feelings (between 3 and 7), and that the mode is simply the only value that repeats itself once. Groups C and D also show some fluctuation, but it is closer to their two modes, 1 and 3, showing a tendency towards greater satisfaction. In its turn, Group B has a majority of answers equal to 1, its mode, and highest possible feeling of valence.

Therefore, it is visible that the groups that used the system (B, C, D) tended to feel more satisfaction. However, a statistical analysis with the Kruskal-Wallis method (used with non-parametric data [75]) showed no statistically significant correlation between the groups. Hence, we cannot reject the null hypothesis in terms of feelings of satisfaction.

As for the feelings of Arousal, Table 5.4 holds the ratings for each group. Again, lower values mean greater feelings of motivation and excitement during the activity. The mode is shown in the last line, in bold. The first interesting aspect to note is that the values from Group A vary a lot, fluctuating between 2 and 6, which indicates neutral feelings of valence. Next, Groups B and C show less variation, with lower values (between 1 and 4), indicating high feelings of excitement. Finally, Group D interestingly shows only two values, 1 and 5, where 5 comes up more. While 1 is the highest value, 5 is the neutral feeling, meaning the visually impaired participants either felt extremely excited, or motivated enough to complete the activity. Moreover, since the last participant from Group D was very anxious and rated her feeling of arousal as neutral, this could be an indication that the others who gave a grade of 5 were also feeling intimidated by the new technology or the activity.

Table 5.4: Levels of Arousal from the SAM questionnaire.

A [no system, no blindfold]	**B** [system, no blindfold]	**C** [blindfold, system]	**D** [system, disabilities]
3	3	2	1
3	2	2	5
6	1	4	1 (**B**)
5	3	3	5
2	1	1	1
5	2	1	5
	3		5 (**B**)
Mode: 3;5	**3**	**1;2**	**5**

A statistical analysis with the Kruskal-Wallis method gave a correlation between Groups A (traditional way of shopping) and C (blindfolded participants), but with **P=0.17**, which does not surpass the 95% relevance threshold. Therefore, we cannot reject the null hypothesis in terms of motivation.

Finally, Table 5.5 shows the scores for feelings of Dominance and, for this dimension, unlike Tables 5.3 and 5.4, higher values indicate greater feelings of control. The last line of the table indicates the mode for each group.

Table 5.5: Levels of Dominance from the SAM questionnaire.

A [no system, no blindfold]	**B** [system, no blindfold]	**C** [blindfold, system]	**D** [system, disabilities]
3	6	7	9
7	9	5	9
7	5	4	7 (**B**)
6	8	5	9
7	8	5	9
9	5	2	9
	5		9 (**B**)
Mode: 7	**5**	**5**	**9**

In Table 5.5 we can see that Group A shows feelings of dominance fluctuating mostly around its mode, 7. Group B has a wider range of scores, from 5 to 9, with a mode that means neutral feelings of control. Group C has the same mode, but its values are mostly equal to or lower than 5. Finally, Group D has an almost unanimous scoring of 9, the highest feeling of dominance. Hence, we can infer that the group with real disabilities (D) felt much more in control than the blindfolded group (C). In fact, the visually impaired participants (Group D) showed greater feelings of dominance than all the other groups, including those with no disabilities that shopped normally (Group A). This could be an indication that the system gave, especially to the participants with disabilities, a feeling of empowerment.

A statistical analysis with the Kruskal-Wallis method showed a correspondence between Groups B and C, and between Groups C and D, with **P=0.02**. Hence, we can say that, in terms of control, there is a significant difference between using the U-NEXT system when you have a real disability from when you have a simulated one. This makes sense, because a blindfolded person is out of their comfort zone, while a person with an actual visual impairment has had time to get used to the visual limitations. We can also say that there is no statistically significant difference between shopping normally (Group A) and shopping with the system (Groups B, C and D). Therefore, we cannot reject the null hypothesis in terms of feelings of control.

5.4.3 Amount of Tasks Execution

Through the system log we can count how many times each user executed certain tasks. As we did in the experiment with the graduate students, we reasoned that the most prominent tasks in the activity were the following three: listen to product information, listen to comments about a product and listen to navigation information.

Table 5.6 shows the amount of times the participants from the first workshop executed these tasks. The first interesting aspect is that both low-vision teenagers did not use any of the 6 navigation tags, while the blind boy used 4 of them. Another notable fact is that the three participants listened to all of the 9 product information tags, and the blind boy scanned some of them more than once. Practically the same happened with the 9 tags with comments about the products. Therefore, there is an indication that, for users with low-vision, the tags with product information and comments are the most important ones, while for blind users the navigation tags are equally relevant. This could be because low-vision users can somehow navigate on their own, but blind people need as much help as they can get from the environment.

Table 5.6: Amount of times users executed the main tasks in the first workshop.

Task	**Blind Boy**	**Low-Vision Boy**	**Low-Vision Girl**
Product Info	12	9	9
Comments	12	8	9
Navigation	4	0	0

Table 5.7, Table 5.8 and Table 5.9 show the results from the second workshop (Group

D) and from the experiment with the graduate students (Groups B and C), regarding the participants' access of functionalities. Each line represents a different participant, and the results from the blind participants in Group D have a (B) next to them. In addition, the last line of these tables, marked in bold, represents the average calculated for each group.

First, Table 5.7 has the amount of times each participant heard the product information tags. It is evident that participants who could see did not use the product information tag very often, probably because they could see such information in written form. However, Group C on average did not scan all the product information tags, while most of Group D scanned some tags more than once. This happened even though Group D has more low-vision participants than blind ones, opposing our initial observation from the first workshop. This also indicates that, for this task, there is a significant difference between the fake and the real visual disability.

Table 5.7: Amount of times users accessed product information.

B [system, no blindfold]	**C** [blindfold, system]	**D** [system, disabilities]
0	6	13
4	6	18
2	5	15 (**B**)
2	7	12
3	8	7
0	7	10
0		7 (**B**)
Avg: 2	**7**	**12**

Since this is a between-group experiment, with one independent variable (U-NEXT system) and three conditions, the appropriate method for statistical analysis is the One-Way ANOVA [66]. Applying this method on Table 5.7 (without the last line) returned $\mathbf{P=7.9^{-06}}$ and $\mathbf{F=3.6}$. Hence, since $P<0.05$, we can say there is a significant difference between Groups B, C and D regarding their use of the product information tags. Therefore, the difference is significant not only between fake and real disability, but also between presence and absence of users' visual impairments.

Moving on to the analysis of the task of listening to comments about products, Table 5.8 shows some changes from Table 5.7. First, Group B displays an increase in usage of the system. This is justifiable because, unlike the product information, the comments are not available in written format, only in audio.

Second, the average in Group C increases slightly, while in Group D it decreases. However, Table 5.8 also shows that most of the participants from Group D used all of the comment tags, while in Group C all but one participant accessed less than 9 tags. This could be an indication of how the users with real disabilities were more comfortable with spatial navigation than the simulated blind. Hence, they were able to follow the tags with more consistency, while the users from Group C skipped a few tags.

Another interesting fact to observe in Table 5.8 is that participants from Group B listened to at most 6 comment tags, 3 below the maximum 9. This indicates they used

Table 5.8: Amount of times users accessed comments about products.

B [system, no blindfold]	**C** [blindfold, system]	**D** [system, disabilities]
4	11	8
6	8	9
5	8	10 (**B**)
5	7	9
4	8	9
4	4	9
4		3 (**B**)
Avg: 5	**8**	**8**

the information in these tags in a more objective manner, mostly to help them in selecting the three items from the shopping list. Hence, they did not listen to comments about products that were not on the list.

In addition, if we compare Table 5.6 with Table 5.8, we can see that the three teenagers from the first workshop used the comment tags similarly to the six adults and one teenager from the second workshop. Again, we remind that the last user from Group D was very anxious, so she tried to finish it very quickly, although not scanning many tags. Finally, applying the one-way ANOVA in Table 5.8 we get **P=0.005** and **F=3.6**. This means there is a statistically significant difference between the three groups, in terms of listening to comments about products.

Regarding the use of the navigation tags, Table 5.9 shows the results for Groups B, C and D. Consistently with Table 5.6, most of the low vision users from Group D did not use the navigation tags. Meanwhile, of the two blind participants, the one that was not anxious did use 3 of the 4 tags. There is also a consistency with Group C, where all but one of the participants used at least one navigation tag. In turn, most of Group B (people using U-NEXT system without blindfolds) did not use any navigation tags. This is probably because, in our simulated supermarket, it was possible to see all the aisles, but in a real supermarket, with many gondolas and corridors, even a person with sight would probably need assistance with navigation.

Table 5.9: Amount of times users accessed comments about products.

B [system, no blindfold]	**C** [blindfold, system]	**D** [system, disabilities]
3	2	2
0	1	0
0	0	3 (**B**)
1	1	0
0	4	0
0	4	0
0		0 (**B**)
Avg: 1	**2**	**1**

For Table 5.9, the One-Way ANOVA returned **P=0.14** and **F=3.6**. Hence, we cannot say there is a significant difference between the three groups related to using the navigation tags.

Our final quantitative analysis is about how many times the participants listened to the shopping list, shown in Table 5.10. Since in the first workshop there was no shopping list, Group A does not go into this analysis.

Table 5.10: Amount of times users heard the shopping list.

B [system, no blindfold]	**C** [blindfold, system]	**D** [system, disabilities]
1	2	1
2	3	1
0	2	1 (**B**)
0	1	2
2	1	1
2	3	1
2		4 (**B**)
Avg: 1	**2**	**2**

It is interesting to note in Table 5.10 that Group B has the smallest average, but most of the participants from this group who used the shopping list tag, did it twice. Considering Group B also had the shopping list in writing, it is a significant number. In contrast, every participant from Groups C and D listened to the shopping list at least once. However, Group D is almost uniform around 1, while Group D varies around 2 or 3 times. This could be an indication of how the memory of those with actual visual impairments is better than the fake blinds' or even than those without visual disabilities. In this case, the one-way ANOVA returns **P=0.45** and **F=3.6**, which means the difference between the three groups, regarding amount of times using the shopping list, is not statistically significant.

5.4.4 Qualitative Feedback

In the two workshops with visually impaired users, we collected qualitative data in the "Conversation" and in the "Debriefing" moments, as explained in the "Case Study" section. In the experiment with the graduate students, we gathered qualitative data through a questionnaire and a debriefing session with all participants after the experiment was done. In the following subsections, we will focus our analysis on the data from the two workshops and use the experiment with the students only as a parameter of comparison, when appropriate.

Shopping Habits

In both workshops, participants reported how hard it is to go shopping on the supermarket. The blind participants said they cannot do it on their own: they need help from either a family member or an employee from the establishment. Those with low vision can go by themselves, but they can have problems with finding the products, if they do not know the supermarket layout. In the case of asking for professional assistance, participants request and have to trust that the employee will seek correct products from the list provided by them. All of them reported on how it is both important and difficult to read information in the packages, such as expiration date, calories or presence of sugar (since some of them are diabetic).

Desires and Expectations

In the first workshop, when asked about how they would like to shop, participants said they had never thought about it before. All they could say was they wished it could be autonomously.

Strategies for Shopping

As strategies for shopping, in the first workshop, participants visited all products around gondolas and then they picked the product of their choice, as this was the scope and instruction for the activity. In the second workshop, even though the objective was different, the participants also tended to explore the supermarket, product-by-product. This possibly was to give them a view of the available options before selecting the products from their shopping list. In this sense, the blind participant who was anxious did not explore it all, she just took the items as soon as she found them.

Main Difficulties

During the experiment, the main difficulty for the participants was to hold the mobile phone in one hand while manipulating other objects (e.g, bag and white cane). In this case, participants were afraid of dropping the phone from their hands. For observers, in a real situation, participants run the risk of forgetting the phone on a shelf. The same type of difficulty was observed in the experience with students, especially Group C.

Pró-Visão participants also had difficulty while they were holding the phone, due to the large size of the phone model chosen by the researchers. This problem can be easily solved by choosing another model or installing the U-NEXT system core in the mobile used currently for consumers.

Finally, most participants (Pró-Visão and students) had difficulty, on the first try, to place the RFID reader in a correct position for the system to read the tag. Participants learned with time that they had to bring the middle of the phone (where the RFID reader is) close to the tags.

System Advantages

The system showed notable advantages over the functionality and time to perform the shopping task. The mobility of the system in a smartphone also allowed participants to have more autonomy during the interaction with the simulated supermarket.

Regarding the functionalities, participants liked having the separation well marked among types of information (price, weight, etc.) for each product present on the shelves.

Opinion and comments from other costumers about the products were helpful in the decision making process. For participants, comments are an additional selection criterion that goes beyond the price and product brand. The comments from other consumers instead of comment made by the manufacturer enrich the trust on the feedback about each product, once manufacturers have interests in making sales.

Regarding the time of shopping, participants think it is faster to use the system than to ask for help to any employee at the supermarket. Besides, they are sure they are buying what they want. When someone else helps them shopping, they run the risk of buying a product that they do not want. Therefore, information on the product expiration would be important to be in the system. Navigation information tags (on the shelves) also help participants to save time, because it allows customers to know which products are in the gondola, without having to search product by product.

Different from students' feedbacks, the Pró-Visão participants understood the synthesized voice used by the U-NEXT system; it did not bother them and they thought the speed of speech was adequate for them. However, they think that speed control can be a useful functionality.

System Drawbacks

Almost all participants used the tact to find the information tags on the shelves. Although participants reported being easy to find it, is impossible to know the tag contents before scanning it. Therefore, participants have to listen to each label to identify its contents. However, after they listened to the tag information, they easily distinguished that there are three different kinds of information in several tags around the supermarket (location, comments and product information). Participants also informed that, once they picked up the pattern of information tags coming before comment tags in the shelf, it was easy to identify them beforehand. A possibility for the system is to create tangible information that identifies the different tag types and their contents.

The navigation tags at the end of the gondolas worked well to inform participants about products specificities. For blindfolded participants (group C) and the blind boy, it caused some confusion, regarding the position of the goods and which direction the consumer must take to achieve their ultimate goals. This way, in some cases, one of the participants needed the help of a third party to find gondolas and product position. Giving a more precise information (e.g. use a GPS system) is a likely solution.

Different from felt by the students, the shopping bag did not disturb most participants. Only participants who use the white cane and need to hold the shopping bag were muddled with many artifacts to hold. A possible idea is to place the RFID reader at the end of the white cane and tags on the floor, as proposed by [73]; that solution could facilitate at least navigation minimizing the number of things to hold.

Summary

Overall, the Pró-Visão participants enjoyed the adapted supermarket, and they wish that all supermarkets had similar functionalities, to support them in shopping with more autonomy. After the experience, some improvements were suggested regarding. First, placing additional information in the product (expiration date, calories, lactose presence, trans fat presence, fat percentage, if the product is recommended for diabetics or people with of allergies). Second, improving the localization system, regarding the quality of message information). Third, reducing the device size. Finally, making tactile differentiation (e.g. Braille) for the types of tags (navigation, product information and comments).

5.5 Conclusion

Shopping in the supermarket is a necessity in modern life that represents a challenge for people with visual disabilities. In this work, we investigate the theme of smart cities, by proposing and studying a smart supermarket scenario. The paper presented a mobile version of the Universal Navigation, Exploration and eXchange with Things (U-NEXT) system. It provides a Natural User Interface that, following Universal Design, aims to help all users with the tasks of finding and selecting products in a supermarket. Then, we presented a case study conducted with visually impaired users. We compared the results of this case study with previous experiments with graduate students without disabilities. Our null hypothesis (H0) was "*There is no difference, in terms of execution time and user feelings of valence, arousal and dominance, between using or not using a system connected to the Internet of Things to perform the tasks of finding and selecting products in a supermarket.*"

In terms of *execution time*, our results showed that there is a significant difference. We found that the graduate students that were blindfolded (Group C) had a similar average time than the users with real disabilities (Group D), but the latter would never be able to shop on their own. In this sense, the system provided them an experience they probably never have had before.

Regarding feelings of *valence*, results showed we cannot reject the null hypothesis. However, most of the ratings indicated high feelings of satisfaction, also observed in the feedback provided during the debriefing sessions.

In terms of feelings of *arousal*, we also cannot reject the null hypothesis. Nevertheless, the ratings from the visually impaired users ranged from neutral to high. The neutral ratings might be a sign of anxiety or intimidation.

Finally, as for the feelings of *dominance*, there is no statistically significant difference between using or not the system. Hence, we cannot reject the null hypothesis. However, this is a good result, because it means the system does not interfere with the users' feelings of control during the shopping activity. Furthermore, the visually impaired users reported higher feelings of dominance than even the users without disabilities.

Therefore, considering that people with visual impairments usually cannot shop on their own, a system that allows them to investigate and explore the environment in a way that augments their senses can be a way to improve their quality of life and autonomy. Hence, by using RFID tags and a system core with a sound output, we have shown that it is possible to provide a low-cost Internet of Things that makes it easier for any user to explore and shop in a supermarket.

As future work, we envision replicating the experiment in a real supermarket, instead of in an experimental setup. This would add more variables, such as flow of people and large background noise. Although the experimental setup also presented environment noise, in a real supermarket it would probably be in a different scale. We will also seek to incorporate in the system the participants' suggestions. Especially, the adding of new information about the products, such as expiration date. In this case, the way we use the RFID tags might have to change, since we have tags in the shelf, not in individual products. In addition, exploring other technologies to implement our solution, such as Arduino, might also be interesting.

A step further in the study would be to explore how to provide more autonomy in real, non-experimental, environments, such as a real supermarket. Doing so in external environments of a smart city, like a busy street, would also present new challenges.

Chapter 6

A Memory Game for All: Differences and Perception as a Design Strategy

6.1 Introduction

From the old arcades that simulated real cars (with chassis, steering wheel and pedals) to gesture-based controls such as the Kinect, the Wii Mote and the Playstation Move, the context of video games has harbored many initiatives that went towards more *natural* interactions. Within this context, the term NUI has been used to refer to devices and technologies that can offer a more direct mapping between the actions in the virtual world and the actions they require the person to perform in the real world [119].

Since the "naturalness" of NUI has been questioned [98, 100], in this paper we attempt to explore it in the context of accessibility in games. In the end, our main goal is to propose a design strategy for games that are both accessible and that provide natural interaction. Our analysis of literature and the design of the game presented in our case study are based on two concepts: differences and perception.

We understand differences from the philosophical stance of Gilles Deleuze [32, p. 28]: "*Difference is this state in which determination takes the form of unilateral distinction*". In other words, differences mean bringing out one aspect of a whole and defining it as distinct from the rest. However, instead of focusing on only one difference, we intend to look at how differences contribute to a better whole. For this reason, we chose Accessibility as the context of our study, since in it we work for the differences, not against them.

Perception, on its turn, we understand in terms of *affordance*, as established by James Gibson [50, p. 127]: "*The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. The verb to afford is found in the dictionary, but the noun affordance is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment.*" Threrefore, in terms of HCI, perception is more than simple input and output; it is also the relationship between the person and the environment or computer system s/he is interacting with. The closer this relationship, we believe, the more natural the interaction will feel.

The coupling between these two elements, differences and perception, is the basis of what we believe is a design strategy towards accessible NUI. This entails the intricate relationship between the person's perception of the world, the world's response to this perception, and the infinite cycle that is generated from that. To further explore these ideas, this paper is organized as follows: in the next section, we will present the work related to our chosen context, accessibility in games using NUI. Then, in the following section we will present our case study, in which we proposed a NUI adaptation of the traditional memory game. Then, we analyze both our case study and the related work under the scope perception and differences. In the final section, we present our concluding remarks.

6.2 Related Work

The following subsections show our search strategy for finding the related work, and then our analysis.

6.2.1 Search Strategy

To find work addressing accessibility in games, we searched through conference proceedings and journals focused on either NUI, games or accessibility. Hence, for **games**, we looked at the Brazilian Symposium on Computer Games and Digital Entertainment (SBGames), and the Symposium on Computer-Human Interaction in Play (CHI PLAY); for **accessibility**, we went through the journal Universal Access in the Information Society (UAIS), and the Conference on Computers and Accessibility (ASSETS); finally, for NUI, we looked at the Conference on Tangible, Embedded and Embodied Interactions (TEI), and the Conference on Designing Interactive Systems (DIS). From this search, we selected papers from the last ten years, i.e., no older than 2008, and that comprehended NUI, accessibility and games, all at once.

We also performed a second search, looking specifically for "memory game", since this was the subject of our case study. We used this string of search on Springer, ACM Digital Library and Google Scholar. Again, we selected papers from the last ten years, that addressed games and accessibility, but this time they did not necessarily have to include NUIs. Our rationale for this decision was not to limit the types of technology considered in the studies. We believe including those papers in our study allows a deeper analysis on the subject.

We performed a third and final search, looking for "enaction AND game", once we realized none of the papers we had found addressed a concept that is important to us, *enaction*, as proposed by Varela et al. [132]. The search databases were the same as from the second search. The selection criteria, however, was papers no older than 2008, and that included NUI, accessibility and games, all at once. From these three searches we came up with a total of 16 papers. After reading them, we have grouped these papers into **four categories**: *memory game*, *health*, *learning* and *adaptation from visual information.*

6.2.2 Memory Game

The first category has four papers. Raisamo et al. [103] created a memory game that both sighted and visually impaired children can play. Players have to find pairs of vibration patterns, provided by a video game controller, which is also used for input. Navigation through the virtual game board has visual and sound aids. The computer screen displays a grid of rectangles, shown in high contrast for children with low vision. Then, different sound pitches represent horizontal and vertical coordinates in the board. The game was tested with seven children with visual impairments. Results indicated good controller usability and that it is possible to use vibration patterns in a memory game. However, forming a mental model of the board was a challenge for some children, so previous training with a tangible representation was necessary.

Delić & Sedlar [33] propose a memory game that is entirely sound-based, including the board and the user input. Hence, there are no tangible artifacts for players to interact with. To navigate between the cards, sounds vary in direction (to represent the horizontal coordinates) and in frequency (to represent the vertical coordinates). The cards hold a word, stored in audio form, and players have to find the pairs of words. A user test was performed with eighteen children, nine visually impaired, and nine sighted. Their results were compared, but authors did not make it clear whether the test conditions were the same for both groups. Sighted children completed the game faster, but with similar number of attempts (card-turning) as visually impaired children.

Kawamoto & Martins [61] present a visuospatial memory game designed specifically for elders. The game consists of four squares, each with a color (yellow, green, red and blue) and a sound associated with it. To win, players must correctly select the squares in the presented sequences, by controlling a hand cursor through the Kinect. The game was tested with ten older adults, and results indicated they found that controlling a cursor with their hand (Kinect) was tiring, frustrating and more difficult than using the mouse.

Winoto & Tang [138] propose two games, both for the visually impaired. The first uses a helmet with five buzzers, each placed on a different location. The player has to repeat a sequence of sounds by turning a smartphone in the directions indicated by the buzzers. Sounds or vibrations indicate if the player was successful. The second game is played on the smartphone, with a piece of cardboard placed on top of the screen. It has a grid of rectangular holes cut through it, representing cards faced down. The player has to find the pairs of cards, by touching the holes to flip the cards. The pairs are always in different columns, a restriction used to reduce the game complexity. Both games were tested with five sighted people, who were either blindfolded or with their eyes closed. Results indicated the first game was easier, despite one of the buzzers (in the back of the head) being difficult to recognize.

In summary, we have four works with five different approaches to memory games (since Winoto & Tang [138] showed two games). Four were exclusive for the visually impaired, so their focus was on translating visual into audio or haptic information. The other proposal, from Kawamoto & Martins [61], focused on elders and therefore attempted to make the interaction simpler by making it gestural. Overall, the papers in the memory game category focused on specific audiences and their needs, in terms of how information is presented and how player input is made.

6.2.3 Health

The second category includes six papers. Geurts et al. [49] present four mini games they designed for the rehabilitation of people with limited motor control. To come up with the games, they used participatory design, involving patients and therapists. The games use different technologies, such as the Wii Mote, the Wii Balance Board and a webcam. They were tested with 21 people, and results pointed towards the importance of game calibration to each player's skills and goals.

Di Loreto et al. [35] propose an action game where the player controls a naval ship that needs to shoot its enemies and avoid obstacles. The game was designed with a *Universal Design* [74] philosophy, so it aims to be fun for everyone and, at the same time, a hemiplegic rehabilitation game. To engage players that are not under rehabilitation, the game was designed to maintain a high level of challenge at all times, and it keeps a score rank, to instigate competition. Displayed during a gaming exhibition, the game was played 700 times by players with and without motor disabilities. Results indicate both audiences were entertained, and that some people played the game several times. To be accessible to people with different motor skills, the game supported multiple input devices, such as keyboard/mouse, joystick, Kinect, tablet, and Wii Board.

Hwang et al. [57] wished to test whether the effects of balancing algorithms in exercising games for people with disabilities persist or change over time. To do so, they created two games and tested them with eight children with cerebral palsy. One is a racing game, where the player controls the speed of a lizard by pedaling a custom bicycle. The other is a shooting game where the player has to hit their adversary by aiming and shooting with a video game controller. Results indicated that, in the course of six days playing these games, the balancing algorithms did not alter player behavior. This happened even after they understood how their efforts were compensated to even the chances between players.

Vandermaesen et al. [130] present a game for the rehabilitation of upper limbs, for people with neurological disorders. The controls consist of four wooden boxes, each with a unique grip for training a specific hand task. Inside the boxes, an Arduino and sensors check if the tasks are executed correctly. The player controls a virtual avatar and has to overcome obstacles that are specific for each box. The game was first pilot tested with five healthy individuals, and then with eight people with multiple sclerosis. Results indicated the game was useful for rehabilitation, and that the controls were easy to learn. However, participants suggested more features would promote long-term playing.

Gerling et al. [48] propose a Kinect game that uses full-body motions and is directed to older adults. The theme of the game is gardening, and there are four gestures the player can make, each mapped to an action: growing plants, growing flowers, making flowers bloom, and catching a bird. To grow flowers, for instance, the player lifts or waves one arm, activating rain. The game was tested with twelve adults with ages from 60 to 91 y/o. Results showed that players enjoyed the full-body gestures, and that the chosen theme appealed to them. However, recalling the gestures was a challenge for most players, so authors suggested it might be better to map gestures closer to real world actions.

Sonne & Jensen [120] present a game for helping children with Attention Deficit Hyperactivity Disorder (ADHD) in controlling their stress. The custom game controller looks like a blowfish, and, to succeed, players have to inhale or exhale into the fish at the right pace. The idea is to disguise breathing exercises into the game. To build the controller, the authors used a sensor to detect temperature changes and LEGO. As a preliminary evaluation, they tested the game with sixteen adults. Results showed that the game can successfully make players relax, but first they need to understand the rhythm they are expected to breathe in and out. Otherwise, they can become anxious, or even hyperventilate.

In summary, from the six papers in the **health** category, four focus on rehabilitation for motor skills, one is directed to elders and one is for children with ADHD. Hence, unlike the **memory game** group, these works are more concerned with *how* the user will interact with the game, and not so much with *translating* information from or to visual, audio or haptic formats.

6.2.4 Learning

This category has three papers. Sánchez, Sáenz & Ripoll [110] present a game of spatial exploration, where the input tool is a wooden carpet with twelve haptic cells on it, simulating a clock. The idea is that blind and low-vision children interact with the game using their bodies, and the main goal is to teach them spatial orientation. To achieve this, they use the hour system and the wooden carpet to orient themselves and navigate in the game. Their objective is to find an object in a virtual environment full of rooms, and a sound cue tells them when they are close to the object. Twenty children with visual impairments tested the game, and results indicated the carpet was easy to use and a helpful tool for learning spatial orientation.

Milne et al. [88] designed a suite of smartphone games that promote Braille literacy for children. As form of input, the games take touch or gestures, and the feedback to the user is through sound or vibration. The Braille is shown in the smartphone screen in an oversized scale, as it is usually done when teaching with non-digital materials, like egg cartons and tennis balls. This means the games are for teaching the Braille encoding, but not to develop the tactile sensitivity. The authors designed the four games following a set of principles: to be accessible, to be educational, to accommodate different skill levels and, finally, to be available for mainstream devices. They tested the games with eight blind children. Results showed children were able to learn some Braille concepts with the game, and that, for the most part, they were able to play autonomously. However, the games did not engage players for a long time, and many children reported they played collaboratively with their sighted siblings, despite the game being designed for the visually impaired.

Vanden Abeele & Schutter [129] present a mini game meant to be played by seniors and youngsters, together. Authors use the terms *enactive knowledge* (proposed by Jerome Bruner [22]) and *enactive interaction* to refer to physical action that requires previous knowledge. As seen in the work of Gerling et al. [48], from the **health** category, it is important for gestures to be mapped close to real world actions. Vanden Abeele &

Schutter [129] also use the term *digital affordance*, referring to how the virtual world of the game must indicate to the player which actions are possible or expected. Hence, the game proposed by the authors has players using the Wii Mote to perform actions such as rotating screws or cleaning a dirty surface by rubbing it. They designed the game thinking of “equality in ease of use”, i.e., the game is meant to be challenging and fun for all ages. A user evaluation with seven seniors and eight youngsters resulted in most participants quickly understanding how to play, and in similar performances between the two age groups.

In summary, from the three papers in the **learning** category, two have specific goals of teaching certain skills to visually impaired children. The other one focuses on how to use previous knowledge to improve interaction. Hence, two use technology for learning purposes, and one uses learning in favor of technology design.

6.2.5 Adaptation from Visual Information

The fourth and final category contains three papers. Yuan & Folmer [142] translated visual information into haptic stimuli, to make a famous rhythm game accessible to the visually impaired. Players must use a special glove that contains small motors in each finger. This way, vibrations indicate which buttons in the plastic guitar controller players need to press at the correct time. Authors conducted a usability study with three blind and nine blindfolded sighted people. Results indicated the glove was successful in translating visual information into haptic stimuli, but with limitations, such as restricting players to an easier game difficulty.

Allman et al. [4] also present an adaptation of an existing musical game, but instead of a plastic guitar, players use a drum kit controller. The visual cues of the game are translated into audio and vibration, the latter occurring in different parts of the player’s body through straps with small motors. There are five straps, which are attached to biceps, wrists and one of the ankles. The haptic feedback tells players when and what to do, e.g., hit the drum’s pedal when there is a vibration on the ankle. Meanwhile, the audio serves to vocalize text (such as instructions or scores) and provides feedback whether the player performed an action successfully or not. The study involved four people with visual impairments in both design and evaluation phases. Players reported the game was fun and easy to learn, but some suggested using their hands instead of drumsticks, to get a better sense of where the drums were.

Morelli, Foley & Folmer [90] propose an adaptation of a virtual bowling game, using the Wii Mote, that has a built-in accelerometer and vibration capability. The game requires the player to hold the controller upwards and then mimic the tossing motion of the real world bowling. The controller vibrates more intensely as the user points it towards the direction of the throw, to guide the visually impaired. Other visual information are given by sound, such as score and how many pins were hit . Six blind adults tested the game and found it fun and easy to play. They suggested adding a multiplayer option and more sounds, such as a cheering crowd, or spatial audio to indicate where the ball hit.

Overall, the **adaptation from visual information** group presented three game adaptations with translation from visual to haptic and sound information. In two of these works, the translation was only possible by restricting the game difficulty. Allman et al. [4] did not have to make this concession, but their translation had another limitation, also present in the work of Yuan & Folmer [142]: players cannot anticipate future moves, since the haptic feedback can only tell them of the immediate required action. All three papers present approaches that go towards assistive technologies, and do not encourage bringing together different types of players.

6.3 Case Study

Thinking of the research opportunities we found in 6.2, we conducted a case study with visually impaired individuals and a memory game we created.

6.3.1 Game Design

The main artifact of our case study is an accessible adaptation of the memory game. In the traditional version, a deck of cards is laid out face down in rows and columns, forming a grid. There are pairs of identical cards, and the goal is to find all the matching pairs by flipping the cards, two at a time. When the player flips two cards, if they are a pair, they are both removed from the board. Otherwise, they are turned face down again. Usually, pairs are represented through images, making it inaccessible to the visually impaired.

In our adaptation, the intention was to maintain the core of the game, and make it accessible to as many people as possible. The physical artifact consists of a board where the cards are laid out, as illustrated in 6.1. It is made of Ethylene-Vinyl Acetate (EVA), and has dimensions of 40cm by 50cm. The board has pockets to hold the cards, allowing a visually impaired player to feel the board with her hands without scrambling the cards. Each pocket has a bump on its top, to mark its location. The pockets form a 5x5 grid, mapped by coordinates: columns are letters from A to E, and rows are numbered from 1 to 5. Hence, there are twelve pairs of cards, and the remaining one is a trap, i.e., it does not match with any other card.

The artifact also includes an Android app that requires a smartphone with Near Field Communication (NFC) capability, because our cards are actually Radio-Frequency IDentification (RFID) cards that need to be scanned by the smartphone. Hence, when the player brings the device close to a card, it is equivalent to "flipping" that card. Furthermore, the act of scanning a card triggers the following:

1. By synthesized voice, the app informs the coordinates of where the card is located (e.g. E-2).

2. The app displays on the screen the image associated with the card, and plays the sound related to that image. The images and sounds can be of animals (e.g. lion), objects (e.g. church bell), or places (e.g. a city or state).

3. By synthesized voice, the app tells the player if this is the first or the second card she has flipped while trying to form a pair, or if it is a trap.

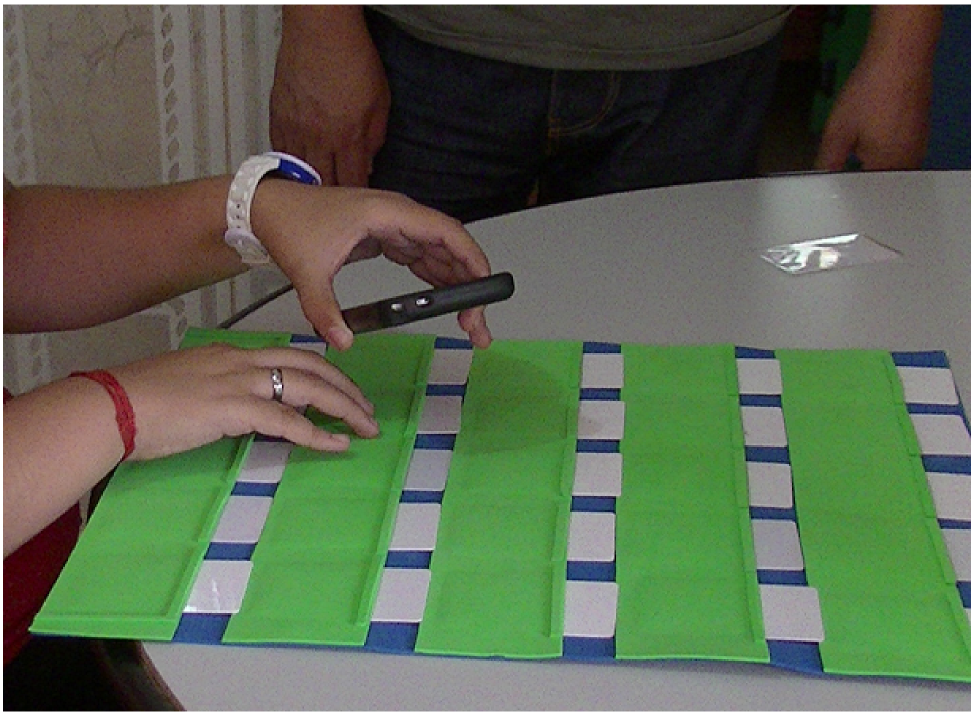


Figure 6.1: Close-up of the game board while a person is playing our memory game.

(a) If it is the *first card*, the player is instructed to flip another card.

(b) If it is the *second card*, the app checks if it forms a pair with the first one. If they do **not**, the player is instructed to scan another two cards. If they **do**, the app asks the player to remove the two cards from the board.

(c) If it is a *trap*, a funny sound plays and the player is informed she fell into the trap. If the trap comes after a first flip of a pair, that flip is reset.

There were no images associated with the physical cards, i.e. they were blank on both sides. This was a design decision made to bring the problem of scrambling the cards to the software, instead of obligating players to physically move the cards around the EVA board. It also brings flexibility to the game, since it allows us to change the images and sounds just in the software. Finally, it is a step towards a "design for all". Having the images directly on the cards brings an advantage to players who can see over those who cannot. They would be less dependent on the coordinates to remember the card locations, whereas the visually impaired, in principle, rely mostly on the coordinates to associate with sounds. Having the images only on the smartphone screen is a smaller advantage, since the image will not be so strongly associated with the location on the board.

6.3.2 Participants and Method

We tested our adaptation of the memory game with a group of four visually impaired individuals, three blind and one with low vision.

They are all part of a non-profit institution called "Pró-Visão", located in the city of Campinas. The organization brings together people from the local community with the goal of social inclusion of the visually impaired. The institution tends to people of all ages, and helps them gain autonomy in everyday activities, such as reading Braille, using the white cane, and signing documents. The activities are conducted by a multidisciplinary team that includes educators, psychologists and social assistants. From the start, our partnership with the institution had the agenda of helping the participants learn new skills by putting them in touch with novel technologies. In return, we got their feedback and constructed new forms of interaction along with them. All of this was done with the consent of the institution and under the regulations of an ethics committee. We presented participants with a consent term, read it to them (aloud or with a screen reader) and all who agreed, signed. It was made clear to them they were not obligated to participate.

Three of the participants from this case study had already been on other activities organized by us, where we brought them different devices, including a smartwatch, smartphones, and Kinect and Leap Motion artefacts. The activity of this case study was the last in a series of six, organized in the course of a year. All activities followed the same format, which we called "workshop". First, there was an ice-breaker, where we introduced ourselves and welcomed new participants. Then, we explained the activity of the day: what were the goals, the technology used and the applications to their routines. In this stage, we could ask them questions about such applications, i.e., how they usually deal with the situation without technology. Next, we had them experiencing the technology, usually one-by-one. Then, each participant answered an individual evaluation through the Self-Assessment Manikin (SAM) [20]. It allowed them to give a spontaneous feedback on how they felt while using the technology. Finally, we had a *debriefing* session, i.e., a group discussion about the whole workshop to get both individual and collective qualitative feedback.

6.3.3 Results

The results can be divided into four moments. First, the initial discussion about their previous gaming experience. Second, observations from while they played the game. Third, the results from the SAM evaluation. Finally, there is the feedback from the debriefing.

Previous Gaming Experience

Participant #1 lost his sight after adulthood, so he said he used to play video games and cards, but has not played anything since. He believes he could play again using a magnifier – since he is not completely blind – but he has not tried.

Participant #2 said she does not play games very often, but when she does, she likes quiz games, on the smartphone. She also told us she has played an adapted memory game at school, but she did not like it. There were different textures and materials to identify the pairs, but she reported it was poorly made.

Participant #3 said she does not care much for games, but has played hangman, word search, and a memory game, all on the computer.

Participant #4 told us he is an athlete, and enjoys physical activities such as skateboarding, spinning tops, and playing sports. He also likes playing with an adapted version of the Rubik's Cube and dominoes, which he can use the common version if it is possible to feel the numbers on the pieces. He also plays chess and checkers, but on the computer. To do so, he uses coordinates for locating pieces and making plays, similarly to what we did in our memory game. He said, however, that if he were to play the physical version, he thinks his opponent would have to read him the whole board, making the game slower.

Playing the Memory Game

Participant #1 adopted the strategy of exploring the third and fourth rows linearly, and then doing the same for the second row. After exploring the area of these rows, he moved on to the fifth row, and then to the first, finding as many pairs as possible. In total, he took 29 minutes to find all pairs. He had some trouble with the RFID reader; sometimes it took him a while to bring the device to the right distance from the card, a problem he had in previous workshops. At other times, he would maintain the reader over a card, and its content kept being repeated. In addition, after there were few cards left, it was difficult for him to find where they were, as he kept feeling the board, trying to find them. Another difficulty he had was in removing the cards from the board after finding a pair, since he could not always remember where they both were. During the game, on occasion, Participants #2 and #4 gave him tips, and it was interesting to note how, even though they were not manipulating the RFID reader, they were still able to remember some of the cards' positions, just from listening to the coordinates.

Participant #2 adopted the strategy of random exploration, i.e., she did not follow a specific pattern to choose which cards to flip. She took 27 minutes to complete the game, and had a lot of difficulty remembering positions of cards she had already flipped. In addition, she was very anxious and kept talking about other topics while playing, making her distracted. Other participants gave her tips from time to time, and she listened to them.

Participant #3 linearly explored the fourth row, then the fifth (bottom), and then she went back to the third, then the second and, lastly, the first. While exploring, when she found a card she thought she knew where the pair was, she marked it to search specifically for its pair. At first, she did so by placing a finger over the chosen card, while she used her other hand to hold the smartphone and scan cards. Later, she began to take the card from its pocket and set it aside. After finding the trap a few times, she also removed it from the board. In the end, she got the second best time in the group: 16 minutes.

The best time, however, was from Participant #4. His strategy was to first scan the four corners of the board. Then, he made a cross by going through the middle row and then the middle column. He easily remembered the positions of the cards, so it only took him 11 minutes to find all pairs.

Self-Assessment Manikin

Individually and right after playing the game, each participant answered the SAM, an evaluation tool for measuring the feelings of Valence, Arousal and Dominance evoked by a stimulus [20]. In our case study, such stimulus is the memory game in its entirety: the

Table 6.1: Results from the Self-Assessment Manikin.

Participants	#1	#2	#3	#4
Valence	1	3	5	1
Arousal	1	3	5	1
Dominance	1	3	1	1

play, the rules, the concrete objects that compose the game (e.g. board, card, smartphone) and the information system that is behind all of it.

We chose SAM because it is the evaluation tool we already used in previous workshops within this institution. In this case study, the goal is not to find correlations, but rather to get the participants' spontaneous reaction to the experience, before the discussion with the whole group.

Each parameter of the SAM has five options, which range from most positive (1) to most negative (5) feelings. Results from all participants, separated by parameter, are shown in 6.1. We can see that Participants #1 and #4 gave the best scores on all parameters, meaning they felt happy, excited, and in control while playing the game. Participant #2 gave neutral scores to all parameters, so she did not feel either too positive nor too negative about playing the game. She was really nervous during the game, so it could explain why she did not report more positive feelings. In turn, Participant #3 felt totally in control, scoring maximum dominance, but was neither excited nor satisfied with the experience. This is probably because she does not like games, and even before playing she said she was not feeling motivated.

Debriefing

During the debriefing session, participants reported not having difficulties with the game. Participant #2 said that she was afraid to drop the smartphone (because it is expensive), and that it was kind of heavy to hold for a long time. Participant #1 thought it was easier to memorize sounds (e.g. the roar of a lion) than spoken words (e.g. the name of a city). They all concurred the number of cards was good. Participants #3 and #4 reported they relied more on spatial location than on the coordinates to memorize where the cards were. Participants suggested playing against a partner could be fun. Another suggestion was to use Braille or at least different textures to mark the location of the cards, instead of just the bumps on the pockets.

One researcher asked participants about the length of the feedback, since every time after flipping two cards, the synthesized voice would say "this is not a pair, keep looking". When asked if this was too long, they said it was good, although some of them thought it would be fine if it was shorter, e.g., "this is not a pair", or just a buzzer. Finally, the social worker who was present during the activity said the game is good not only for the visually impaired, but also for people with intellectual impairments. She said the sound calls attention and can stimulate them a lot.

Table 6.2: How each group worked with players' perception and differences.

GROUP	PERCEPTION	DIFFERENCES
MEMORY GAME	Players have to identify patterns of sound, image or vibration. Input is through buttons, touch, gesture or sound. Rarely there is redundancy between them.	Focus on a specific characteristic: visual impairment or old age. Design strategy is to provide help just for the chosen issues.
HEALTH	Feedback mostly visual. Emphasis on physical rehabilitation, so input is either by gesture, touch or custom control (breath – by Sonne & Jensen [120], bicycle – by Hwang et al. [57] or grips – by Vandermaesen et al. [130]).	Focus on rehabilitation of specific health issues. Aside from Di Loreto et al. [35], there is no concern to include healthy players.
LEARNING	Game has visual representation, even those for the visually impaired. Feedback is either sound, vibration or visual. Input is through gesture or touch. Little concern for redundancy.	Focus on a specific characteristic: visual impairment or old age. Design strategy is to provide learning based on the chosen issues.
ADAPTATION FROM VISUAL INFO	Visual representation substituted by vibration or sound. Input is through buttons or gestures.	Focus on visual impairments. Design strategy is to provide assistive technology through sensory substitution.

6.4 Discussion

To be able to reflect upon our case study and our literature research, we start by summarizing the information from the four categories we established in Section 6.2. Therefore, Table 6.2 shows how each literature group treated perception within their games, and how they dealt with differences, i.e., what was their target audience and how they worked for it.

6.4.1 Differences

we can see that, in terms of differences, most related works chose one disability or health problem to focus on, and designed their game around that. One of the exceptions is Raisamo et al. [103], that despite having focused on visual impairments, showed a concern for allowing sighted children to also play the game. To do so, they complement the visual information with other senses (haptic and audio), instead of substituting it. Another exception is Di Loreto et al. [35], who focused on hemiplegic rehabilitation but explicitly with a Universal Design [74] philosophy. This led them to a multimodal approach, i.e., their game was compatible with an array of different controllers so that people with many types of motor disabilities could play. They also made sure the game was interesting for people without disabilities, so they kept it challenging and interesting, instead of focusing only on the rehabilitation aspect. Lastly, Vanden Abeele & Schutter [129] work towards "equality in ease of use", so that their game can be equally fun and challenging for both elders and youngsters. To achieve this, they used the concept of "enactive interaction", i.e., employing the player's previous experience with real-life physical actions. This meant the game had visual virtual elements that elicited or afforded to the player the expected actions. The work of Gerling et al. [48] highlights the importance of using such previous knowledge, since the gestures they designed did not have a direct correlation with real-world actions.

From these three exceptions, we can take an important lesson about dealing with differences in the design of games with natural interaction: there are ways to include as many people as possible. Multimodality of inputs is one alternative, and redundancy of information for several senses (vision, hearing and touch) is another. However, these are mostly solutions for physical disabilities, since they focus on the medium, and not on the information itself. To deal with cognitive difficulties, such as those that might be caused by aging, there is no clear pattern of solution. In particular, two works designed games specifically for older adults. Kawamoto & Martins [61] trusted the technology (Kinect) would be enough to make the interaction more natural for elders. Gerling et al. [48] relied on the same device, but went a bit further by worrying about the gesture design and the theme of the game, making sure it was attractive for the audience. Following a different direction, Vanden Abeele & Schutter [129] designed a game specifically for youngsters and seniors to play together. To achieve this, they based the game actions on real-world activities. In a similar fashion, Sonne & Jensen [120] has the player inhaling or exhaling into a fake tangible version of a pufferfish, to make a virtual fish inflate or deflate. This, in turn, is supposed to help children with ADHD learn breathing exercises.

Hence, the related work we found that deals with cognitive issues does so by mapping game actions close to real-world actions. This points us towards a connection between such mapping and natural interaction, as it had already been argued by Skalski et al. [119]. However, what the authors did not point out [119] – and these works indicate to us – is that inclusion is part of this equation. From the related work we analyzed, those that revolved their design around a specific technology or target audience made little room for including more players. In contrast, works that tried to bring differences together were more successful in making technology an ally instead of a barrier. In the end, we believe this is what constitutes a natural interaction: enabled by technology, for as many people as possible.

In this sense, in our case study presented in 6.3, we proposed a memory game that intended to suit players with distinct preferences, backgrounds and game strategies. The four visually impaired people who played the game were able to complete the game, and all felt in control while doing it – even the one who was not entirely motivated by the activity. Furthermore, in the design of our memory game we did not focus on disabilities, i.e., our adaptation was not meant to be exclusive for the visually impaired, for instance. However, we had to consider disabilities players might have, to achieve a design as inclusive as possible.

In this sense, we could push our game design towards a more natural interaction. The most evident issue is that holding the RFID reader (i.e. the smartphone) seemed to cause discomfort and fatigue. In addition, for Participant #1 it was difficult to bring the device to right distance. Hence, we could either use a lighter reader, or eliminate it altogether. In this case, we could have pressable buttons behind the cards. This solution would also make the board more self-contained, and the game more inclusive for players with motor impairments – as long as the buttons do not require much strength to be pushed. However, maintaining the game accessible to people with hearing disabilities, there would have to be some sort of screen on the board, displaying the contents of the card that was flipped, the same way the smartphone does.

6.4.2 Perception

In terms of **perception**, we conclude from 6.2 that the **health** and the **learning** groups usually took some form of exercise – physical or intellectual – from the real world and tried to translate it into a game. In turn, both the **memory game** and the **adaptation from visual information** groups usually focused on translating information from one sense (vision, touch and hearing) into others. In most cases, this went more in the direction of sensory substitution than on providing redundancy. These alignments are probably a reflection of similar intentions between the works from these groups. While the **health** and the **learning** groups aim to turn into fun something that is usually perceived as boring, the **memory game** and the **adaptation from visual information** groups adapt existing games to reach specific audiences.

In our case study, since we made an adaptation to an already existing and well-known game, we tried to preserve as much as possible its original features. We managed to maintain the idea of placing the cards in a grid, while at the same time making it possible for people to run their hands through the cards without taking them out of order – an important feature for the visually impaired. The major change we made, in the name of *differences*, was to create a metaphor for flipping the cards. This was necessary to take the focus away from the visual information, since the idea of the flip is to reveal the image contained on the hidden side of the card. Hence, in our adaptation, players access the cards' contents using an RFID reader.

This device became the medium between the player and the cards, i.e., players did not touch the cards to "flip" them. One advantage of this metaphor was that most of the participants from the case study were already familiar with RFID, so it was not something completely new to them. The only one new to the technology was Participant #4, who had the fastest time, and who gave maximum score for the SAM parameter of dominance, so the device was not a problem to him. In opposition, Participant #1 had already used the device before, and this time had the same past problems of placing the reader at the right distance. Still, he reported maximum feeling of dominance.

Hence, the RFID reader has, to the participants of our case study, an *affordance* of revealing sound information, since that is how they had used it before. However, if we were to eliminate the reader, the affordance would go to the cards, bringing our adaptation closer to the original game. If we place pressable buttons behind the cards to trigger the information, we would still be using a metaphor, but maybe one that reaches people who have never used an RFID reader, and people who cannot hold the device to play. In addition, players would have both hands free. This is important, in particular, for the visually impaired, because they would be able to explore the board faster. However, it could actually benefit all players who would wish, for instance, to mark a specific card's location with one of their hands.

Having both hands free would also address the problem of remembering where are the two matching cards the player needs to remove from the board. In the traditional memory game, after finding a pair, the two cards are removed from the board, either by the player or by the computer (in the virtual version). In our case study, we maintained this idea, but for most of the time it was difficult for participants to remember the location of both cards. Usually, they knew where the last card they scanned was, but not its pair. This constituted a further memory exercise, especially if they found the pair by luck. That is why Participant #3 would either mark a card with her free hand, or take it away from the board. Therefore, if players had both hands free to play, they could, for instance, press one card, keep their hand over that card, and press another card with their other hand, hence keeping track of both "flipped" cards.

6.4.3 Difference and Perception as a Design Strategy

From the previous discussion, we can say that, from the related work, the **health** and the **learning** groups started from the *differences* and went to deal with *perception*, while the **memory game** and the **adaptation from visual information** groups went from *perception* constraints to dealing with *differences*.

We argue that this relationship can be cyclic. For instance, a game from the **health** group that is mostly rehabilitation for patients (*differences*), is not interesting for people who do not need those exercises. However, if the design also went back the other way around, i.e., considering how this game could be interesting, for instance, for the visually impaired, adaptations would be necessary (*perception*). These adaptations would probably involve providing more forms of input and translating visual information to other senses. This completes a cycle, going from a *differences* to a *perception* point-of-view. Now we argue that this cycle could go on, e.g., from the adaptation arises an issue of teaching the visually impaired a skill necessary to play the game (*differences*). This is important to our goal of natural interaction because it points to a design strategy that depends on both *differences* and *perception*; in fact, it lies in-between them.

For this reason, in our case study, from the very beginning, our design went back and forth. We started with a Universal Design perspective, and chose an existing popular game to apply it. Our rationale behind every design decision for the memory game adaptation was based on how it could accommodate more differences, and what these differences would require in terms of perception. As we presented in 6.3, there is still room for improvement for making the game more accessible. Therefore, we propose that the strategy for designing a game that provides both *accessibility* and *natural interaction* should strive to find a balance between accommodating differences between users, and providing multiple channels for the perception of information. Furthermore, such balance is dynamic, i.e., it requires constant transition between the two elements, differences and perception. As we saw from our related work analysis, staying in one extreme leads to a solution that is either too exclusive for one audience, or uninteresting for other people.

6.5 Conclusion

In this paper we found and analyzed papers that addressed accessibility in games using NUI. Such analysis suggested a focus on disabilities, and sensory substitution as a common strategy to deal with them. From this, we presented our case study, involving visually impaired people and our adaptation of the memory game. Our case study allowed us to put to test a design strategy, where the idea is not to focus on specific differences, as the literature we found did with disabilities. Instead, differences have to be incorporated into the design, as many of them as possible. Therefore, we argue that the design of natural interaction should provide the common ground for differences. But how to do that?

The answer lies in the element of perception, the relationship between person and environment, which is unique to each person. In our case study, we saw how our memory game had distinct affordances for each player. Some devised strategies and tried to beat the game fast, while others just wanted to finish it. Hence, the game was inclusive, not just because it allowed visually impaired people to play it autonomously, but also because it became a common ground for different people.

This two-way relationship brings us to a design strategy, which is actually the coupling between the elements of differences and perception. In our case study, we designed a game that was meant to be played by as many people as possible, and to do so, instead of sensory substitution, we strived for sensory redundancy. We succeeded in terms of translating specific visual information to other senses, but we overlooked the fact that, forcing players to have only one free hand, could hide underlying tactile information. For visually impaired players in particular, this became an issue that did not harm the gameplay, but it did push our design a bit away from the naturalness we were hoping for. Therefore, we saw that to design natural interaction is not just about technology, and it is not just about the person using the technology. It is about what lies in-between, that only exists when the differences and the perception intertwine.

Chapter 7

An Enactive Perspective on Emotion: a Case Study on Monitoring Brainwaves

7.1 Introduction

Instead of making humans adapt to the computer world, ubiquitous computing, in essence, is about technology becoming invisible and blending into the human world [134]. The concept of Tangible User Interface (TUI) [58] extended this idea by proposing to transform digital information into concrete objects, which could be done with architectural elements (e.g. walls or doors), everyday objects (e.g. books or cards), or ambient conditions (e.g. sound, light or airflow). With the same intent but with a different approach is the concept of *enactive systems* [60], which rejects the idea of a goal-oriented and conscious interaction. Instead, in an enactive system, the person's body and spatial presence is the conduit that allows a non-conscious interaction with the system. The authors drew the *enactive* part from the concept of enaction proposed by Bruner [22], in the sense of "learning by doing", but it also resonates with what Varela et al. [132] called *enaction*. In particular, considering what are the frontiers of the body is important when talking about the design of enactive systems, and we take on the view of the Embodied Cognition (EC) theory, as it considers the cognitive system to be a network composed of the environment, the body and the brain [128].

Hence, in this paper we explore the possibilities brought by Brain-Computer Interface (BCI), in terms of non-conscious interaction in an enactive system, and analyzed through a lens based on phenomenology, such as that of enaction [22, 132] and of Embodied Cognition [128]. As the name implies, BCI is the interaction between a person and a computer system using signals from the brain [69]. One way of providing BCI is to capture and record the electrical activity in the brain using electrodes attached to the surface of the head, a process called Electroencephalography (EEG). Until recently, EEG systems were restricted to hospital and laboratories, but now they are available to the general public through consumer-grade EEG devices [87]. Two examples of such technology are the Emotiv EPOC [37] and the Neurosky MindWave [96]. Both devices are capable of providing metrics on two emotional states: *attention* and *meditation*, i.e., how much a person is focused and how much she is relaxed. We can relate these metrics to the "arousal" and "pleasure" dimensions of the circumplex model of affect [108]. The values provided by the devices come from interpretations that their proprietary algorithms make of the person's brain waves. The availability of EEG devices, as well as the simple measures they can provide on a person's emotional state, make them an interesting option for using BCI in ubiquitous scenarios, or in enactive systems.

One major challenge that needs to be overcome by BCI technology is personalization [69]. This entails, for instance, adapting the system's algorithms to each person's individual brain waves, considering external factors such as possible distractions, or adapting to the person's mood on different occasions. Personalization might also be a desirable quality for Universal Design (UD), the approach to design that aims to make interactive products suitable for the widest possible range of users without requiring adaptations [36]. In a context that potentially tends to a variety of user characteristics and requirements – such as pervasive computing – it is crucial to provide usability and accessibility to all of them.

Such is the challenging scenario in which this work is situated. Therefore, in this paper, we will investigate if and how a consumer-grade EEG device, the Neurosky MindWave, can contribute to the design of an enactive system. Moreover, we wish such design to be informed by an enactive perspective, the theoretical basis from which the concept of enactive systems came. So, the paper is organized as follows: in Section 7.2 we present a literature review on BCI, in Section 7.3 we explain what is the enactive perspective, in Section 7.4 we present our case study with the MindWave, in Section 7.5 we discuss the results of the case study and its implications for the design of enactive systems; and in Section 7.6 we give our concluding remarks.

7.2 Emotion Captured through EEG Devices

Literature has investigated gaming as a common application for research on EEG devices. For instance, [46] had four people play an audio-only horror game while wearing the Emotiv EPOC on their heads. The ambient sound of the game is meant to cause tension, as well as some of the goals players need to achieve, such as moving unarmed and evading enemies. The game was designed to have an equal number of moments of *calm* and *fear* (ten of each), since the author's goal is to test whether these states can be detected with the EEG device. After statistical analysis of the raw EEG data, the author found indications that it is possible to differentiate states of fear and calm, although more testing is needed to actually prove that. In addition, the author emphasizes that the electrical activity mapped by the EEG is unique for each individual, but some patterns emerged during the analysis.

Also in the gaming context, [47] used a simulation game to test whether the Neurosky MindWave can be used to detect the effects of *surprising* events on players. To do so, the authors made two versions of the game: one for control and another for experimental conditions. Twenty people played the game, ten for each version. Both versions had a moment for baseline recording – where players were asked to remain calm and inactive for five minutes – and a training phase, to teach the basic controls. The difference between the two versions was in the next phase, where players could either experience seven surprising events (experimental conditions) or regular gameplay, without surprises (control). Then, the final stage of the game is the same for both versions, with three surprising events. Results indicated it is possible to detect the effects of surprise using MindWave and that, furthermore, players from the experimental conditions group were more relaxed when they encountered the surprises on the final phase than the players from the control group.

Still in gaming context, [26] investigated if video game events can cause changes in player's emotions. They used the Emotiv EPOC in an experiment where twenty people played one of three different commercial games, each from a distinct genre: racing, shooting and pool. For each game, the authors established which kinds of events caused either *frustration* or *excitement*, the two emotions chosen for the study. The events were manually annotated by researchers, by watching video footage of participants playing the games. The authors used the Emotiv API, which measures emotion using a normalized value between 0 and 1. The authors converted this intensity into a time series, so that it would be possible to study its correlation with the game events. Hence, authors used linear regression, and found that (1) emotion peaks occurred about half a minute after game events, and (2) there is a strong correlation between game events and emotion peaks.

Also investigating how to apply BCI devices in games, [39] does it with emphasis on music and sounds. More specifically, the authors explore how to detect emotions elicited by certain sounds, to see if it would be possible to adapt a game's music according to the player's mental state. In this investigation, they compare the Emotiv EPOC and the Neurosky MindWave. They concluded that both devices are able to detect the four emotions needed for the experiment (*fear*, *joy*, *happiness* and *sadness*), despite the MindWave having less sensors. Furthermore, the participants reported they preferred MindWave because it felt more comfortable. The authors also performed an experiment to see if players can consciously create specific music notes using only a BCI device. At first, it was difficult for participants to reproduce notes by only listening to them. The solution authors found was to associate the note with an image and a gesture, which reduced the training time by half.

On a similar fashion, [40] developed a software that allows people to create drawings using the Neurosky MindWave. Artificial Intelligence (AI) algorithms interpret the brain signals, according to brain wave rhythms classifications, such as *arousal*, *anxiety* or *relaxation*. Twenty people experimented the software and, according to the authors, it gave them the opportunity to express their creativity in an unconscious way. After statistical and signal analysis, authors concluded that certain brain wave rhythms, as well as the levels of *attention* given by MindWave, are only relevant for the creative process of people with arts education.

On the context of education and e-learning, [133] tests whether a person's levels of *attention* measured by the Neurosky MindWave change while watching a video and performing a task – counting how many times an event occurs in the video. The authors also test if a distraction within the video can have an effect on the levels of attention. The authors' final goal is to help improving performance assessment and evaluation for training videos, especially with students in remote locations. Results indicated that there was no significant difference in the levels of attention between participants who counted right and those who counted wrong. Furthermore, there was no significant difference in levels of attention between participants who saw the distraction and those who did not see it.

Finally, on the context of decision-making, [112] executed an experiment with ten participants where the Emotiv EPOC monitors their EEG while they perform a task. The authors' ultimate goal is to design a BCI system for decision-making. In the experiment, participants had to compare two sets of geometric forms, shown separately, and saying whether they were identical or not. They did this in two stages, each consisting of 56 comparisons. After each stage, participants answered a questionnaire about their feelings during the experiment. In the results analysis, authors did not find a relationship between the participants' self-reported perceptions and the Emotiv EPOC's readings of five possible emotions (*engagement*, *frustration*, *meditation*, *excitement*, and *long-term excitement*).

In summary, from the selected works we can notice a few trends in the domain of BCI and consumer-grade EEG devices. First, the applications we saw are still on an experimentation stage, and are all for individual use and in a controlled environment. Hence, the matters of a pervasive and personalized BCI have not been worked on yet. Second, most of the works performed some kind of statistical analysis on the EEG data. However, there is not a consensus on the statistical method, even among those that employed the same EEG device. Third, all works selected a few emotions to try to detect and classify in their experiments. This is an indication that emotion is being viewed as a type of information to be processed. In this sense, we can also see that there is not a consensus on the emotions that were selected; each study chose a different set.

These trends identified in the literature point to an open opportunity of investigation with regard to the design of ubiquitous systems using BCI. In this paper we take an approach that encourages a tight coupling between the system and the person using it, thus promoting pervasiveness. This approach does not treat emotion as just information, but instead views it as part of the whole cognitive process. In other words, such approach treats body, mind and computer system as a whole. We detail this approach in the next section.

7.3 Emotion through the Lens of Enactive Approaches

An **enactive system**, as proposed by Kaipainen et al. [60], consists of a "*dynamic mind-technology embodiment*", where the interaction is based on involvement of the body without a conscious control of the system, in contrast with the conventional interaction that is totally conscious and oriented by goals. The interface, then, can become implicit to the point of being directly linked to the person's physiological readings. In this case, Kaipainen et al. [60] relate the concept of *enactment* to the idea of *learning by doing*, proposed by Jerome Bruner [22].

Bruner's idea of learning through action comes from a differentiation of three experiences that happen in the learning process: the action-based (enactive), the image-based (iconic) and the language-based (symbolic). Such separation characterizes how higher-order cognition arises from joining the action of a task with its simple components [41]. This resonates with the idea that metaphoric concepts emerge from basic bodily experiences [45]. These views of the learning process are also compatible with the definition of *enaction* by Varela et al. [132]: "*In a nutshell, the enactive approach consists of two points: (1) perception consists in perceptually guided action and (2) cognitive structures emerge from the recurrent sensorimotor patterns that enable action to be perceptually guided*". Hence, while perception is guided by action, cognitive structures – or higher-order cognition processes – are enacted, thus allowing the action to guide the perception.

This definition of enactive approach is a reflection of what Varela et al. [132] characterize as a shift in cognitive science; one that goes from seeing the world as independent and extrinsic, to viewing the world as inseparable from the processes of self-modification. Furthermore, this shift means looking at cognitive systems not in terms of input and output, but in terms of **operational closure**. According to the authors, "*A system that has operational closure is one in which the results of its processes are those processes themselves*". Hence, such systems are autonomous in that they are defined by internal mechanisms of self-organization, not in a way that *represents* a detached world, but in a manner that *enacts* a domain that is inseparable from the embodied cognitive system.

Autonomy, however, cannot be defined exclusively by internal processes that recursively depend on each other. According to Thompson and Stapleton [127], an autonomous system – such as the human cognition – also has to regulate its interactions with the world, i.e., its network of internal processes needs to be **thermodynamically open**. Having this active regulation is what characterizes the adaptive autonomy that is necessary for **sense-making**, which, in turn, is the behavior the system adopts according to the *significance* and *value* that it gives to its current environment. Furthermore, such norms the system places on the outside world are not predetermined or fixed, but *enacted* by the system through its autonomy. Therefore, in the same way that the two points of the enactive approach described by Varela et al. [132] are interdependent, **autonomy** and **sense-making** also feed one another.

In essence, sense-making is the reasoning behind motivated action, which is a form of self-regulation, especially if it involves *affect*. Hence, the enactive approach sees that sense-making is as much about cognition as it is about *emotion* [127]. Moreover, in the same way that the cognitive system is not seen as simply input and output, emotion is not looked at as a type of *information*, to be transmitted back and forth from a person to a computer system. It is in this sense that Boehner et al. [18] propose an **interactional** approach to emotion, instead of an informational one.

The interactional approach "*sees emotions as culturally grounded, dynamically experienced, and to some degree constructed in action and interaction*" [18], which is a vision compatible with the enactive approach. Furthermore, in terms of computer systems, the interactional approach shifts the focus "*from helping computers to better understand human emotion to helping people to understand and experience their own emotions*". In turn, this implies that computer systems designed with the interactional approach do not aim to guess the *correct* emotions people are feeling, but instead, their goal is to encourage individual or collective awareness and reflection on the emotions that were evoked during interaction. This way, feelings are not pre-existing facts, but something that develops with conversations and interactions, where an initially vague, ambiguous or even confusing sensation may consolidate into a meaning. Again, this is in accordance with the enactive approach and with Bruner's [22] idea of learning by doing.

In this sense, although Kaipainen et al. [60] relate their vision of an **enactive system** with Bruner's theory, the minimalist example they provide seems to be inclined towards the informational view of emotion. The enactive system they describe consists of sensors that make psycho-physiological readings, which, in turn, are interpreted by the computer to determine the user's emotional state from a possible set of emotions. Then, a computer-generated character changes its facial expression to match the user's interpreted emotion. Finally, this change should cause a reaction in the user, which would reflect on the psycho-physiological readings, closing a feedback loop that can be infinite. In terms of the enactive perspective we have presented so far, this example seems off due to how it treats emotion as information, but in a way it also can bring a person to have awareness and reflect upon her own emotions. Hence, looking at the enactive system in terms of **autonomy**, it has *operational closure* because of its internal feedback loop, but its internal processes are not *thermodynamically open*. In order for that to happen, they would have to somehow regulate their interactions with the outside world. One way of doing that would be to allow the meanings of emotions to emerge from interaction, instead of encoding them into specific patterns. For instance, Boehner et al. [18] present as an example of an interactional approach a system called "Affector" [115]. It consists of two video windows on each side of adjoining offices, each displaying real-time footage of the neighbor's office. The video, however, is distorted based on filters defined by the users according to what they feel is the affective mood of the office. In this example, the feedback loop between person and video represents the operational closure, while the distortion filters the user can apply to the video serve as self-regulation mechanisms, thus providing the thermodynamic openness and, consequently, *sense-making*.

Expanding this discussion to what we found in the previous section, we can see that, since most works focus on interpreting the EEG data, the trend in literature is also on the operational closure. Furthermore, since most systems we found were for individual use and on controlled environments, there is little room for sense-making, especially for the co-construction of meaning for the emotions that arise during the experiments. Bearing this in mind, in the next section we present our case study, where we take these experimental conditions found in literature as the starting point to our goal: an **enactive system** that follows the enactive perspective by providing both *autonomy* and *sense-making*.

7.4 Case Study

The object of our case study is the use of a consumer-grade EEG device in experimental conditions and with a single user at a time, following the trend found in literature. Our goal is to design an *enactive system* using the enactive perspective presented in the previous section. Therefore, we aim to see how far we can go with the EEG device as a starting point.

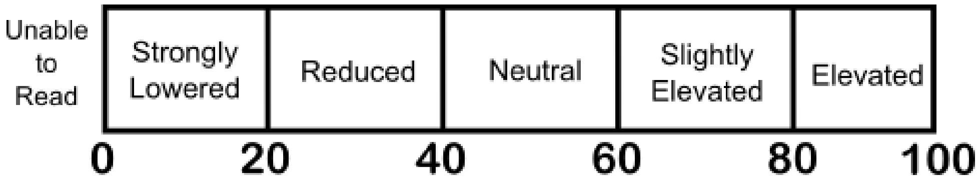


Figure 7.1: Neurosky's eSense scale for both Mediation and Attention levels, based on developer documentation.

7.4.1 Technical Setup

The technical setup for our case study is twofold: the EEG device and the software which participants interacted with during the experiment.

EEG Device

In this study, we adopted a consumer-grade, non-invasive EEG device called MindWave, from Neurosky [96]. It is a brainwave sensing headset that has a single dry sensor the user places on the forehead. MindWave can communicate with the computer or a smartphone through Bluetooth, and can provide the following outputs: Attention value, Meditation value, brainwave band powers (e.g. delta, theta, alpha, beta, gamma), and raw EEG wave samples at 512Hz. We chose to work with the two first outputs, Attention and Meditation. They are calculated by the device's proprietary algorithm, called *eSense*, which returns a value on a scale that goes from 0 to 100. According to the Neurosky developer documentation [95], the eSense scale has a meaning according to five different ranges, that indicate the current level of Attention or Meditation: from 1 to 20 it means a "strongly lowered"; from 20 to 40 it means "reduced"; from 40 to 60 it is "neutral" (baseline); from 60 to 80 it means "slightly elevated"; finally, from 80 to 100 it is "elevated". The meter value of 0 indicates the calculation is not being performed, probably due to poor reading of the signal. The scale with all this information is represented in Figure 7.1.

The developer documentation [95] also highlights how these ranges are relatively wide because the eSense algorithm has dynamic learning, so it sometimes adjusts to fluctuations that occur normally with EEG readings, and are particular to each person. Neurosky affirms this is what allows the device to work with a variety of personal and environmental conditions, maintaining reliable and accurate results. They also encourage developers to fine tune their use of the ranges according to the needs of the application; e.g. trigger an output only for values above 60.

On one hand, the eSense level of **Attention** indicates the magnitude of the person's mental focus, like the one that occurs during intense concentration. Factors that can bring it down are distractions, anxiety or wandering thoughts. On the other hand, the eSense level of **Meditation** corresponds to the *mental* calmness or relaxation, so simply relaxing the muscles of the body might not result in immediate rise in the Meditation level, although relaxing the body can help in relaxing the mind as well. In addition, closing one's eyes might be an effective method for increasing the Meditation level, since it turns off the mental activities that process images from the eyes. Factors that can lower the Meditation levels are the same that lower Attention levels, plus agitation and sensory

Figure 7.2: The minimalist interface of our quiz, showing a relaxing image.

stimulation.

Software: Quiz

The software consists of a quiz, with a total of twelve Yes/No questions, taken from the appendix of the study of Sparrow et al. [121]. We took six questions the authors classified as easy (e.g. "*Are dinosaurs extinct?*"), and six that were considered hard (e.g. "*Do insects feel hunger?*"). The software was developed using the Scratch [105] programming language, because it was easy to integrate with the MindWave device, and it allowed us to program the software rather quickly.

The ultimate goal of the quiz is to detect whether relaxing and disturbing images can have an effect on the levels of Attention and Meditation captured by the MindWave. In this sense, the idea for the interface was to maintain the player's focus on the images, so other visual elements were kept to a minimum. In order to do that, the questions were read by a synthesized voice, and no text was displayed. The player only had three options of buttons: "Yes", "No", and a button to repeat the question. Figure 7.2 shows an example of the interface, displaying a relaxing image – the picture of a puppy.

The quiz is divided into three moments, each containing four questions. In the first moment, the player can only see the three buttons on a white background. After the player answers the fourth question, s/he enters the second moment, where each question has a different disturbing image as a background. Finally, after the player answers the eighth question, s/he goes into the third moment, where each question has a relaxing background.

The four **disturbing** images we chose were the following: the Napalm girl from the Vietnam war, three bare-chested starved children, a Somalian adolescent holding a rifle, and the explosion on the World Trade Center from the 9-11 plane crash. In turn, the **relaxing** images were these: a sleeping kitten, a puppy, reclining chairs in front of an ocean view, and a colorful sunny beach with a hammock attached to a palm tree.

Table 7.1: Questions from the quiz, with their corresponding answer, difficulty and set.

SET	DIFFICULTY	QUESTION	ANSWER
A	Easy	Are dinosaurs extinct?	Yes
A	Easy	Does 5 plus 7 equal 30?	No
A	Hard	Do insects feel hunger?	No
A	Hard	Is the average age of a human eyelash 150 days?	Yes
B	Easy	Are there 15 months in a year?	No
B	Easy	Is the formula for water H20?	Yes
B	Hard	Is a quince a fruit?	Yes
B	Hard	Is Krypton's atomic number 26?	No
C	Easy	Is a stop sign red in color?	Yes
C	Easy	Are there 24 hours in a day?	Yes
C	Hard	Do all countries have at least two colors in their flags?	No
C	Hard	Is myrmecophobia fear of ants?	Yes

7.4.2 Design of the Experiment

For every participant, the images always appear in the same order, although the order of the questions can change. As shown in Table 7.1, the twelve questions are distributed between three sets: A, B and C, where each set contains two easy and two hard questions. The sets are used to organize the permutations that can be applied during the experiment. These permutations are the following: ABC, BCA and CAB. In other words, when the first permutation was active, the participant experienced the questions from group A with the white background, then the questions from group B with the disturbing images, and, finally, the questions from group C with the relaxing images. Within the groups, the order is never altered, i.e., no matter the permutation, the questions from group A always appear in the order shown in Table 7.1. The software has a configuration screen where the researcher can choose between the three permutations before the participant starts answering the quiz. This was made to add a bit of randomness to the order of the questions.

The experiment with our quiz and the EEG device MindWave was designed to be *within-group*, i.e., all participants experience the same conditions. The experiment was performed during a class of a 1-semester Human Factors course, and 16 students were present on the day of the experiment. In the classroom, one by one, students went to where the setup for the experiment was located: the MindWave device, a headphone, and a chair in front of the table with the laptop that was running the software. Before calling a participant, the researcher cleaned MindWave's forehead sensor, and selected one of the question permutations in the software. After the participant was called, the researcher helped with placing the headphones and the MindWave, which s/he wore throughout the entire quiz.

During the semester, the students were learning how to plan and execute formal experiments in the context of HCI [66], so this experience was presented to them as an example. Hence, instead of acting only as participants, students were also asked to act as observers after participating in the experiment, paying special attention to the body language of the current participant. Along with explanations about the workings of MindWave, this was the only instruction they received before the experiment started; details about the software were kept a secret, to maintain the surprise once they saw the images. In addition, the use of headphones was intended to keep the questions a secret as well, since they were only presented in audio format.

Another intentional design choice was only allowing the player to answer "Yes" or "No" in the quiz. This way, they have to guess, and cannot, for instance, skip a question. In addition, the software also does not provide feedback on whether the selected answer was right or wrong. This decision intended to minimize distractions.

After each participant completed the quiz, they were given a form with questions about the experiment, and also with a space for them to write their observations of other participants. The questions they had to answer were the following: (1) *Did you feel an impact seeing the disturbing images?*; (2) *Which image shocked you the most?*; (3) *Did you feel an effect seeing the relaxing images?*; (4) *Which image relaxed you the most?*.

At the end of the experiment, we also conducted a debriefing session to gather their oral impressions about the experiment. Therefore, we gathered both quantitative and qualitative data. **Quantitative data** consisted of the measures of time to answer each question, and measures of the attention and meditation levels per second. These were all gathered automatically by the software. **Qualitative data**, then, consisted of the answers from the forms, the ideas from the debriefing, and the written observations made by the students and by another researcher.

Finally, the **independent variables** of our experiment are the *difficulty of the questions* (easy or hard), and the *background during the quiz* (white, disturbing image, or relaxing image). In turn, our **dependent variables** are *time to answer a question*, *attention level*, and *meditation level*.

Furthermore, our null hypotheses are the following:

- **H0A:** There is no significant difference, in terms of *time to answer a question*, between seeing a white background and seeing an image.

- **H0B:** There is no significant difference, in terms of *time to answer a question*, between answering an easy question and answering a hard question.

- **H0C:** There is no significant difference, in terms of *attention level*, between seeing a white background and seeing an image.

- **H0D:** There is no significant difference, in terms of *attention level*, between answering an easy question and answering a hard question.

- **H0E:** There is no significant difference, in terms of *meditation level*, between seeing a white background and seeing an image.
- **H0F:** There is no significant difference, in terms of *meditation level*, between answering an easy question and answering a hard question.

7.4.3 Quantitative Results

First we tried to reject the null hypotheses H0A and H0B, both related to the dependent variable of time to answer a question. To do so, we calculated the average times each participant remained on one of the three backgrounds (white, disturbing or relaxing), and on the two types of question difficulty (easy or hard). The results are on Table 7.2.

Table 7.2: Average time (T) and levels of Attention (AT) and Meditation (MD) for each participant in the different types of images and question difficulties.

	WHITE			DIST.			REL.			EASY			HARD		
	T	AT	MD	T	AT	MD	T	AT	MD	T	AT	MD	T	AT	MD
P1	4,5	80	55	4,8	67	47	5,3	71	49	4,7	72	51	5,0	73	49
P2	4,5	75	46	4,3	54	44	5,3	57	40	4,2	64	33	5,2	61	51
P3	5,0			5,5			4,8			3,8			6,3		
P4	5,0	51	44	4,3	46	32	5,3	56	53	4,3	56	45	5,3	48	43
P5	4,0	41	44	3,5	70	46	5,0	68	63	3,5	58	54	4,8	62	51
P6	4,5	67	49	4,8	64	56	4,0	65	50	3,8	74	46	5,0	59	56
P7	4,8	30	51	5,5	24	67	5,0	42	49	4,5	25	55	5,7	37	57
P8	5,0	67	60	5,3	73	79	4,3	75	70	4,2	70	72	5,5	73	68
P9	5,0	63	22	4,8	43	35	5,3	51	26	4,2	56	25	5,8	51	29
P10	3,8	42	40	5,3	64	36	4,0	74	47	4,2	66	57	4,5	56	25
P11	4,5	35	60	4,8	37	42	4,5	40	77	3,7	37	53	5,5	38	64
P12	6,0	47	80	5,0	56	81	4,3	58	67	4,7	53	81	5,5	53	73
P13	5,3	33	60	4,5	23	53	4,3	30	69	4,0	20	57	5,3	35	63
P14	5,8	28	42	4,3	50	73	3,5	34	57	4,2	36	54	4,8	37	57
P15	6,8	62	63	5,0	41	53	4,5	43	54	4,8	54	60	6,0	47	55
P16	5,0	89	63	4,3	75	79	3,8	58	61	3,5	82	64	5,2	71	69

For the null hypothesis H0A, we performed three times the T-Test for two independent means. Comparing the samples from the "White" column with the samples from the "Disturbing" column, the test returned a **P=0,29**. With the samples from the "White" column and the "Relaxing" column, we got a **P=0,14**. Finally, comparing the "Disturbing" column with the "Relaxing" column, the T-Test returned **P=0,41**. Therefore, we *cannot* reject the null hypothesis H0A. Regarding the null hypothesis H0B, we performed the T-Test for the samples from the "Easy" and the "Hard" columns, and the result was **P=0,25**. Hence, we also *cannot* reject the null hypothesis H0B.

Then, we proceeded into trying to reject the null hypotheses related to the MindWave measurements. At this point, it is important to note that there was some problem with the MindWave readings for participant P3, so that data was not considered in the following analysis. The next step, then, was to try to reject the null hypotheses related to the levels of Attention, H0C and H0D. To apply the T-Test on this data, we calculated the average levels of attention for both dependent variables, as shown in Table 7.2. The T-Test for comparison between the "White" and the "Disturbing" columns returned a **P=0,73**. Between "White" and "Relaxing", the result was **P=0,86**. Finally, for the "Disturbing" and "Relaxing" columns, the test returned **P=0,35**. Therefore, we *cannot* reject the null hypothesis H0C. Then, applying the T-Test to the samples from columns "Easy" and "Hard" returned a value of P=0,49. Hence, we also *cannot* reject null hypothesis H0D.

Lastly for our quantitative analysis, we tried to reject null hypotheses H0E and H0F, related to the levels of meditation. We also calculated the averages of the readings provided by the MindWave device, to be able to apply the T-Test, and the results are shown in Table 7.2. Between columns "White" and "Disturbing", the test returned **P=0,44**. Comparing the samples from the "White" and the "Disturbing" columns, the results was **P=0,18**. Finally, between the "Disturbing" and "Relaxing" columns the T-Test returned **P=0,86**. Therefore, we *cannot* reject the null hypothesis H0E. The final T-Test, comparing the samples from columns "Easy" and "Hard", returned **P=0,93**, which also means we *cannot* reject the null hypothesis H0F.

7.4.4 Qualitative Results

First, we will look at the results from the post-experiment questionnaire. For the first question, "Did you feel an impact seeing the disturbing images?", of the sixteen participants, twelve answered they did feel an impact. Most reported they felt the image distracted them enough to cause difficulty in answering the question; some even highlighted how distracting it was the fact that the images were not related with the questions. Some participants also reported feelings of surprise from the sudden appearance of the images. From the four participants who said they were not affected by the images, one gave no explanation, two claimed the images were well-known, and one said once s/he realized the images had no relation with the questions, s/he stopped paying attention to them, staying focused on the questions.

For the second question, "Which image shocked you the most?", twelve of the sixteen participants reported they found the image of the starving children to be the most disturbing. Two recalled the 9-11 image, one mentioned the image of the adolescent holding a rifle, one mentioned the Vietnam girl, and one participant said none of the images was shocking.

For the third question, "Did you feel an effect seeing the relaxing images?", nine students said they did not feel an effect. Of the other seven participants, one said the relaxing image took her eyes away from the answer buttons, where they were to get away from the disturbing images. Another participant said she felt "peace and joy". One student said she perhaps felt relief, and that the images seemed less distracting than the disturbing ones, but maybe not relaxing. Another participant reported thinking "Wow, that's nice!", but then turned the focus back to the questions. Lastly, one participant said that the kitten made her smile a little.

For the last question, "Which image relaxed you the most?", nine participants reported not remembering any specific image. Interestingly, all but one of them remembered a specific disturbing image. Of the remaining seven participants, one said the puppy was the most relaxing image, three said it was the beach, and three said it was the kitten.

Regarding their observations of their colleagues' body language, there were interesting results. Despite receiving the same instructions, each participant had their own ways of interpreting their colleagues' gestures. On one hand, some reported literal body language, like: moving fingers and feet, raise eyebrows, look up, move shoulders or head, intensity of blinks (quick, long or none), hand on chin, swallow, look away, dilated pupils, scratching, crossing legs, and beating on the table. On the other hand, there were observations associating direct meaning to their colleagues' expression: peaceful, "good expression", doubt, tension, discontentment, upset, nervous, uncomfortable, and indifferent. There were also some cases of a middle-ground, such as: "I don't know (eyes and mouth)", "whatever (shoulders)", "mocking laughter", and "signaling doubt with the lips".

Finally, on the debriefing session, participants gave good insights about the experiment. They pointed how knowing you are being observed is a possible bias; a few even admitted they tried to restrain their body language. Another bias could be of participants answering the questions quickly just to get over with the quiz as soon as possible. Regarding the questions, some said they had difficulty paying attention to the audio. They said the synthesized voice does not cause emotional interference, but its pronunciation can be confusing. Regarding body language, the students highlighted how they saw some people moved parts of their bodies when there were disturbing images, and how some participants tried to hide their reactions, for instance by putting their hand on their faces. They also recalled there were people who would look away from the screen to think. The students also felt that the relaxing images were easier to ignore, and a lot of them admitted the could not remember most of the images, or even of the questions from the quiz. Finally, they suggested improvements such as: changing the order of the images, giving a small pause between the questions, displaying the images on a larger screen to raise the impact, providing a more immersive atmosphere through lighting or sounds, displaying animated images, and making the "Yes" and "No" buttons appear with a delay, since their color is distracting.

7.5 Discussion Towards an Enactive Scenario

The quantitative results reported on the previous section did not allow us to find significant differences in the data from our experiment. Even working on the data, making it ranked according to the ranges from MindWave's documentation (Figure 7.1), did not allow us to find correlations – despite providing an interesting option for visualization. This could be due to a number of factors, starting with the eSense algorithm. Since it is programmed to automatically adjust to fluctuations that occur in the EEG readings, such adjustment might not be, for instance, quick enough to adapt to sudden changes. During our experiment, the time participants spent on each question was relatively small: usually no more than five seconds. As reported by [26], emotion peaks can occur about half-minute after the event that triggered them. Therefore, it is possible that the EEG device was not able to detect in time the emotional reactions participants experienced, although these experiences in fact existed according to our qualitative data.

Other possible reason is found in [47], a work that reported how people who encountered surprises earlier were more relaxed when they encountered later surprises than those who only experienced one surprising event. In a way, our qualitative data points to this effect, since the disturbing images – which appeared first – were very striking for most participants, while the relaxing images – which came afterwards – were usually ignored or not easily remembered. Hence, during our experiment participants could have experienced some sort of numbness that prevented MindWave from detecting emotional reactions.

One last reason can be provided by looking at the works of [133] and [112]. The first found there was no significant difference between attention levels in people who performed a task wrong and those who performed it right. The other work reported finding no relation between the self-reported perceptions of emotions, and the EEG device's readings. These two works are examples of how the data from an EEG device might differ from the results we actually see. In particular, the case of [112] is very similar to ours, since our quantitative data did not provide insights that were present in our qualitative data, like the impact the disturbing images had on the participant's concentration.

In fact, it is important to note how much richer the qualitative data was than the quantitative data. While the MindWave only measures levels of attention and meditation, the observations elicited a much wider variety of emotions, like peacefulness, doubt, tension, discontentment, and indifference. This is coherent with the interactional approach [18], which views emotion as much more than information. The way the participants *interpreted* each other's emotions, based only on body language, is a step towards emotion as a cultural, social and collaborative construction, like Boehner et al. talked about. To follow the interactional approach, then, our quiz would have to harbor this kind of social meaning-making. Observing another person play the quiz can lead to reflections on what that person might be feeling and what the images might be triggering for her, which, in turn, can lead to a self-reflection about one's own feelings when presented with the same experiences. Like the "Affector" example [115], our quiz could provide some sort of real-time output of how a player is feeling – like a video footage, or even the EEG reading – and allow other players to transform that output according to their own interpretations of it.

Providing a mechanism such as this would be a way to make our quiz *thermodynamically open*. For it to have *autonomy*, however, its internal processes would have to be recursively interdependent – which, in the current state, they are not. A way to do that would be to incorporate feedback loops, similar to what Kaipainen et al. [60] propose. On an individual level, we could make the quiz environment responsive to the player's EEG readings. For instance, if the readings indicate a high level of Meditation, an agitated music could play on the background, the ambient lighting could glow in warm colors, and the computer monitor could display disturbing or distracting images. If the Meditation levels went down, then calm music would play, ambient lights would glow in cold colors, and the displayed images would be comforting or relaxing. On a social level, we could make it so that it is not the current player's EEG that is affecting his environment, but someone else's. This way, players feed each other's environments, which could lead to co-construction of meaning if players are aware of whose emotions is affecting their environment. Again, a real-time video footage of the person, or some representation of her EEG data would suffice, as long as the interpretation of that data is left open-ended.

Such flexibility is important not only to allow sense-making to occur, but also because EEG readings are unique for each individual, as noted by [46]. Therefore, if we are envisioning a pervasive system that responds to non-conscious control, it is beneficial to consider individual differences. In this sense, a user-centered approach like Universal Design is interesting for a technology paradigm that needs to respond to the presence of different individuals in a seamless and unobtrusive way [36]. Considering EEG readings are so particular, it would be impossible to create one solution, based exclusively on them, that contemplates every user – a fact reinforced by how our quantitative analysis found no correlations. However, enactive systems, if designed with the enactive perspective we presented, have the potential to contemplate a wide variety of users, especially with the social component that emerged from our qualitative results. For instance, in our examples where one person's emotional state affects another person's experience, as long as each one can develop their own sense-making of the other's situation, they are communicating with each other in an universal way. The ambient lights, the sounds, and the images, all embedded in the player's environment and making use of multimodality and multimedia, tend to a wide range of human abilities, skills and preferences.

7.6 Conclusion

In this paper we investigated how the MindWave EEG device can potentially contribute to the design of *enactive systems*, a concept of dynamic coupling between mind and technology. In our literature review, we saw how the use of EEG devices is still experimental, and meant for individual use in controlled environments. We also saw a focus on statistical analysis of the EEG data and on classification of emotions. We took these trends as a starting point to our case study, which involved an experiment that tested whether MindWave could detect emotional reactions from the participants. Although our quantitative data did not allow us to make correlations between the experimental events and the EEG readings, our qualitative data proved to be quite rich. In particular, once we looked at it using the lens of the enactive perspective, we found significant contributions that could elevate our experimental setup to an enactive system. The concepts of *autonomy* and *sense-making* were crucial for this process, since they provided us with a scaffold to look at how the interactions with the system could be more pervasive and less goal-oriented.

In this sense, the social component emerged as an important factor not only for co-constructing emotions, but also for tackling the problem of personalization. Pervasive or ubiquitous computing needs to reach the widest possible range of users, without the need for special adaptations. Universal Design, then, is almost a necessity, and we believe enactive systems, with the enactive approach, are a viable path towards it.

Chapter 8

Conclusion

Natural User Interfaces (NUIs) started as a term to define a new interaction paradigm, one that used the body in ways that went beyond the restrictions of the mouse and keyboard. Literature, however, did not provide a consensus on what naturalness means in the context of a technology that is evolving to become increasingly pervasive and invisible. Within this same context, literature also did not characterize naturalness in the context of Accessibility, which entails both Assistive Technology (AT) and Universal Design (UD).

Therefore, in this thesis we tried to answer two research questions:

1. How to characterize Natural User Interfaces (NUIs) in the context of a constantly evolving technology?

2. How to make NUIs accessible to all, considering the same technological context?

In Chapter 2, we started to delineate the characterization of NUIs in the context of Accessibility, by means of a systematic literature review. It allowed us to have an overview of the state of the art, and to identify the literature gaps. Most of the papers we found dealt with rehabilitation or health issues, usually proposing Assistive Technologies for specific problems. There was few works that followed Universal Design, or that explored ubiquitous technology. Furthermore, most research agendas followed classic Human-Computer Interaction (HCI) approaches, i.e., with a focus on usability and ergonomics.

In Chapter 3, we adopted such approach and proposed a set of heuristics for NUIs. This was our first step towards answering our research questions, so we decided to start out by using the lens of classic HCI. Hence, for the first research question, we were able to characterize NUIs through usability heuristics, providing both a design and an evaluation tool for this interaction paradigm. Furthermore, we applied our heuristics in two Assistive Technology case studies, so that it was a beginning for the second research question, as we explored one of the elements of the Accessibility context.

In Chapter 4, we added Universal Design – the other element of Accessibility – into the mix. We used artifacts from Organizational Semiotics (OS) to describe our research, which, in turn, was a way of characterizing NUIs. Through three case studies – one with Universal Design (UD) and two with Assistive Technology (AT) – we were able to analyze how the starting point of the design of a NUI can define whether it will be AT or UD.

We concluded that starting from technical and technological requirements, usually leads to an AT, whereas if we begin with social and pragmatic requirements, we get UD. This observation was important for both of our research questions, as it is related to the current technological context, and it does provide a characterization of the design of NUIs in such context, while considering aspects of Accessibility.

In Chapter 5, we presented the design and evaluation of an ubiquitous system for smart supermarkets, which we made under the Universal Design paradigm. This case study started with a pilot test with HCI researchers, and then went through two formal experiments, one with graduate students and another with visually impaired people. The smart supermarket system in itself is a contribution for our research questions, as it provides a real-world example where the current technological scenario is present together with NUI and with Accessibility. The experiments, conducted following formal protocols for setup and analysis, provided us with positive results regarding the quantitative parameters of execution time and of the three parameters from the Self-Assessment Manikin (SAM) – valence, arousal and dominance. These parameters, along with everything we developed in the previous chapters, seemed to help us characterize NUIs in the context of Accessibility, but only as far as the lens of classic HCI permitted. In other words, we came close to the border of where the conventional methods and lines of inquiry could take us.

In Chapter 6, then, we seeked new theoretical references to help us come up with our own definition of what natural means within the context of NUIs and Accessibility. So, in the case study of the redesign of the classic memory game, we brought the perspective on *differences* by Gilles Deleuze [32] and the approach to perception by means of *affordances*, proposed by James Gibson [50]. We used these two references to reach a design strategy that cycles through the two perspectives, to constantly seek which differences the system is accommodating, and how it can incorporate more affordances to include even more differences. This design strategy and the new theoretical references represent a big step towards the answer to our research questions, but we found one more referential that seemed essential to form our understanding of natural.

Therefore, in Chapter 7 we introduced the concept of *enaction* into the theoretical basis of our work. Although O'Hara et al. [100] presented the "embodied interaction" paradigm as an interesting line of inquiry for investigating NUIs, it only made sense to the context of our research once we matched it with the *enactive approach* proposed by Varela et al. [132]. More specifically, the elements Thompson & Stapleton [127] highlighted to describe enaction were an important part of this chapter, and allowed us to characterize naturalness more thoroughly. Furthermore, we also found that the interactional perspective on emotion by Boehner et al. [18] works well with the concepts of enaction, and should be further explored to find new ways of evaluating NUIs. Finally, the case study with the EEG device was a necessary step before imagining an ubiquitous and inclusive scenario that would employ this technology. However, joining the interactional perspective on emotion with the ideas of non-conscious control from the enactive systems of Kaipainen et al. [60], gave us a new outlook on NUIs in the current technological context.

In summary, our characterization of NUI started with an overview of literature, which confirmed what O'Hara at el [100] stated about the approach through ergonomics and usability being the most common one. Then, we adopted this approach and established a set of heuristics to design and evaluate NUIs, and they were put into practice in two Assistive Technology case studies. Afterwards, we used the Organizational Semiotics (OS) artifacts to organize the stakeholders, anticipated problems/solutions, and requirements of our research as a whole. This allowed us to gain an understanding of how to design NUIs that either are Assistive Technologies or have Universal Design. Then, we designed our own NUI scenario, a smart supermarket with Internet of Things, ubiquitous technology and Universal Design. We evaluated this scenario using formal experiments and quantitative metrics. Although the scenario was successful, we realized that our understanding of naturalness needed a new set of theoretical references, as the classic HCI methods were not enough. So in our next case study we proposed a memory game, using differences [32] and perception [50] as a design strategy. Although the two references provided us with new insights to our characterization of NUIs, it still seemed like we needed a perspective on interaction, that looked beyond the cognitive and motor skills. This was important due to the technological context we are considering in our research questions, which is pervasive, ubiquitous and constantly changing. That is why in our last case study we chose an EEG device and explored how it could be used as a form of non-conscious control of a system. Then, we were able to bring a new perspective on interaction to our characterization of NUIs, one that considers the involvement of the entire body: enaction [132].

Therefore, our characterization of NUIs has three main elements. The first is *differences*. As we saw in Chapter 4, in order to go towards Universal Design, we have to start from the requirements of the social layer. We chose Deleuze [32] as our philosophical stance because of how he sees differences as making us what he calls 'univocal': "*The essence of univocal being is to include individuating differences, while these differences do not have the same essence and do not change the essence of being – just as white includes various intensities, while remaining essentially the same white.*" Therefore, in our concept, NUIs should strive for inclusion without segregation. Particularly for the pervasive scenario we have now, it is important that people in special conditions can participate and have access to information technology and computer systems, but such participation should be in equal terms to those who do not share the same conditions.

The second element is *affordances* (or perception). This concept was coined by Gibson [50]: "*The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. The verb to afford is found in the dictionary, but the noun affordance is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment.*" Therefore, while in the first element we consider the differences, in this element we ponder how these differences relate with the environment and/or the technology that is present in this environment. That is why the two concepts are intertwined, as we argued in Chapter 6. In the design process of NUIs, we must constantly go from one to the other if we want to both have a system that is inclusive, and to know how inclusive it is.

The third and final element, presented in Chapter 7, is *enaction*, from Varela et al. [132]: "*In a nutshell, the enactive approach consists of two points: (1) perception consists* *in perceptually guided action and (2) cognitive structures emerge from the recurrent sensorimotor patterns that enable action to be perceptually guided.*" This definition is purposely circular, as the first point refers to the whole-body interaction, and the second point refers to what the body perceives and learns from this interaction, which, in turn, will serve as feedback to the next whole-body interaction, and so on. Given the technological context we are considering in our research questions, it was utmost important to find a reference that saw interaction as an experience of the entire body: mind, brain, perception, limbs, etc. As we are increasingly being immersed into technology, to the point where we are not entirely aware of what is part of a computer system and what is not, it is crucial to understand that the elements of the interaction are not entirely black in white. Hence, the circular definition of the enactive approach allows us to look at such interaction as a whole; we are no longer separating system from human, because the boundaries are not so clear anymore.

Going back to our research questions, then, we can say that differences, affordances and enaction characterize NUIs and guide their design to be accessible to all. This, of course, poses new research questions. First, how do we evaluate NUIs, in the currently pervasive and ubiquitous technological context? The theoretical references we brought in Chapter 7 pointed to some interesting paths for answering that question. The interactional approach to emotion [18] has insights into assessment of emotions, that could be translated to NUI evaluation. For instance, instead of using deterministic and quantitative scales that try to categorize emotions, the authors show the use of abstract ways for users to describe how they feel. In fact, the authors also point to how a collective setting makes the assessments richer; to them, emotion is culturally and socially constructed.

This social perspective takes us to another research question: how should NUIs deal with a constantly changing social scenario? Our original research questions considered the technological scenario and its continuous evolution. However, societies also evolve, as new rules and behaviors are either incorporated or discarded. In this case, pervasive and ubiquitous NUIs would have to somehow adapt to these changes. For instance, in our smart supermarket scenario from Chapter 5, what if there is a social divide between people who consume products from animal origin and those who do not, to the point where one side would not want to receive recommendations from the other? How would the system adapt to that? Would it require people to create a profile and choose a side, or would it remain the same and treat everyone equal? Although the latter does seem like the "Design for All" solution, maybe society would not want that, so who decides how to remain a NUIs for all: the designers, the users or the system? In particular, how does an enactive system [60], which has a feedback loop between person and system, would behave in this situation?

Considering another side of the social perspective, one research question that arises is this: how to design NUIs using the existent Participatory Design (PD) techniques and tools? Traditionally, PD practices use pen and paper, which makes them not entirely accessible to people with disabilities (e.g. the visually impaired). Making these practices inclusive for all is not trivial, and we have started to work in this direction [76], but there is still a long way to go. For instance, an idea is to take advantage of the current maker culture and the availability of several electronic components to allow anyone to make functional prototypes to convey their design ideas. This would be done following the molds of a PD practice called “BrainDraw” [92], but instead of drawings, we would use electronics and craft materials. Making the PD practices more technological has the potential to make them more accessible, but it also poses the challenge of making this technology usable for the dynamics of the participatory practices.

These questions are all difficult to answer, so we present them as possible future work. The main contributions of this thesis, then, are the following:

- Characterization of the current scenario for NUIs, from the perspectives of technology and Accessibility. This is the general contribution of our work, as it comes from the overview of the thesis.

- A set of heuristics to the design and evaluation of NUIs, in the context of Accessibility. Although part of the very early stages of our work, these heuristics still represent an important contribution to the field of Natural User Interfaces, especially through the lens of classic HCI.

- Design of NUIs informed by Organizational Semiotics (OS) artefacts.In this thesis we have filled them out ourselves to help in the characterization of NUIs in the context of Accessibility. This allowed us to gain insights into how NUIs can be Assistive Technologies or have Universal Design.

- Design and evaluation of an ubiquitous and pervasive system for smart supermarkets. We followed Universal Design to propose a NUI that was inclusive and viable, i.e., we considered design constraints that intend to make the solution possible to implement on a scale larger than the experimental settings we built.

- Design strategy that considers circularly the aspects of differences and perception, in order to come up with NUIs that follow our characterization. This iterative process should guide designers who wish to create solutions with Universal Design, while always considering the technological requirements to do so.

- An enactive perspective on NUIs. This should help designers in looking at the interaction with NUIs for all, not only in terms of cognitive and motor elements, but as a whole-body experience. Furthermore, the enactive perspective should also help in understanding that “body” is not limited to the corporeal meaning, but it also entails mind, perception and the technology that is involved in the interaction.

Therefore, although we were able to answer our research questions – and point to some new ones – we had to limit the scope of our study to be able to execute it. Perhaps, the greatest limitation is that, although we are dealing with Design for All, our case studies involved, among impaired people, only the visually disabled. This was the population we had access to, thanks to a partnership with the “Pró-Visão” association, but it was extremely relevant nonetheless, considering how visual most computer systems – even NUIs – are. We would have liked to work with other populations, such as children, people with cognitive or hearing disabilities, and elders. However, we still feel like the results we achieved have contributions for Universal Design, since we did always try to consider how to include even the possible audiences that would not partake in our experiments. Another line we delimited was on the technologies we explored. As NUIs grew in popularity, many devices and hardware have been released over the years while this thesis was in progress, but we did not have access to all of them. The ones we did, we tried to put into the best possible use.

In conclusion, Natural User Interfaces (NUIs) showed up with the promise of an interaction that was more natural than the traditional mouse and keyboard. Terms such as "easy to learn", "intuitive", and "easy to use" were employed to try to describe the naturalness of NUIs, but they did not seem enough. Furthermore, they also did not take into account the technological context that is increasingly engulfing everyone. In this thesis, we seeked to make clearer the characterization of NUIs, and we chose Accessibility as a way of considering the context of a technology that embraces all people. Throughout the work presented here, we have been able to characterize NUIs in terms of heuristics, of Organizational Semiotics artifacts, and of systems with a variety of technologies, such as the Kinect, smartwatches, the Internet of Things, RFID sensors, and EEG devices. In the end, we were able to bring forth three elements we believe condense the meaning of natural interaction: differences, affordances and enaction. Together, these three elements should help in the design of the NUI concept we have proposed in this thesis.

Bibliography

[1] Microsoft kinect for windows. , http://www.microsoft.com/en-us/kinectforwindows.

[2] Amaia Aizpurua, Idoia Cearreta, Borja Gamecho, Raúl Miñón, Nestor Garay-Vitoria, Luis Gardeazabal, and Julio Abascal. *Extending In-Home User and Context Models to Provide Ubiquitous Adaptive Support Outside the Home*, pages 25–59. Springer London, London, 2013.

[3] Malek Alaoui, Karine Lan Hing Ting, and Myriam Lewkowicz. The urge for empirically-informed design of social-oriented aal applications – the example of 2 aal projects. *Procedia Computer Science*, 27:379 – 388, 2014. 5th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion, DSAI 2013.

[4] Troy Allman, Rupinder K. Dhillon, Molly A.E. Landau, and Sri H. Kurniawan. Rock vibe: Rock band®computer games for people with no or limited vision. In *Proceedings of the 11th International ACM SIGACCESS Conference on Computers and Accessibility*, ASSETS'09, pages 51–58, New York, NY, USA, 2009. ACM.

[5] Leonelo Dell Anhol Almeida and Maria Cecília Calani Baranauskas. Universal design principles combined with web accessibility guidelines: a case study. In *Proceedings of the IX Symposium on Human Factors in Computing Systems*, pages 169–178. Brazilian Computer Society, 2010.

[6] Adriana G. Alves, Ana Elisa F. Schmidt, Karla D.P. Carthcat, and Regina C.L. Hostins. Exploring technological innovation towards inclusive education: Building digital games – an interdisciplinary challenge. *Procedia - Social and Behavioral Sciences*, 174:3081 – 3086, 2015. International Conference on New Horizons in Education, INTE 2014, 25-27 June 2014, Paris, France.

[7] Samsung Electronics America. Samsung galaxy gear. http://www.samsung.com/us/mobile/wearable-tech/SM-V7000ZKAXAR.

[8] Mohsen Amiribesheli and Hamid Bouchachia. A tailored smart home for dementia care. *Journal of Ambient Intelligence and Humanized Computing*, Dec 2017.

[9] Carmelo Ardito, Paolo Buono, Maria Francesca Costabile, and Giuseppe Desolda. Interaction with large displays: A survey. *ACM Comput. Surv.*, 47(3):46:1–46:38, February 2015.

[10] Mirjam Augstein, Thomas Neumayr, Renate Ruckser-Scherb, and Sabine Dielacher. *Collaboration Around an Interactive Tabletop in Rehabilitation Settings*, pages 425–442. Springer International Publishing, Cham, 2016.

[11] Gilles Bailly, Jörg Müller, and Eric Lecolinet. Design and evaluation of finger-count interaction: Combining multitouch gestures and menus. *International Journal of Human-Computer Studies*, 70(10):673 – 689, 2012. Special issue on Developing, Evaluating and Deploying Multi-touch Systems.

[12] Steve Ballmer. Ces 2010: A transforming trend–the natural user interface, 2010.

[13] M. C. C. Baranauskas, C. S. de Souza, and R. Pereira. I grandihc-br—grandes desafios de pesquisa em ihc no brasil. *Relatório Técnico. Comissão Especial de Interação Humano-Computador (CEIHC) da Sociedade Brasileira de Computação (SBC)*, pages 27–30, 2014.

[14] M. Cecília C. Baranauskas. Social awareness in hci. *Interactions*, 21(4):66–69, July 2014.

[15] M. Cecília C. Baranauskas, Juliano Schimiguel, Carlos AC Simoni, and Cláudia Bauzer Medeiros. Guiding the process of requirements elicitation with a semiotic-based approach – a case study. In *Proceedings of the 11th International Conference on Human-Computer Interaction*, pages 100–111, 2005.

[16] Ig Ibert Bittencourt, Maria Cecília Baranauskas, Roberto Pereira, Diego Dermeval, Seiji Isotani, and Patrícia Jaques. A systematic review on multi-device inclusive environments. *Universal Access in the Information Society*, 15(4):737–772, Nov 2016.

[17] Florian Block, Daniel Wigdor, Brenda Caldwell Phillips, Michael S. Horn, and Chia Shen. Flowblocks: A multi-touch ui for crowd interaction. In *Proceedings of the 25th Annual ACM Symposium on User Interface Software and Technology*, UIST '12, pages 497–508, New York, NY, USA, 2012. ACM.

[18] Kirsten Boehner, Rogério DePaula, Paul Dourish, and Phoebe Sengers. How emotion is made and measured. *International Journal of Human-Computer Studies*, 65(4):275–291, April 2007.

[19] John Bolton, Mike Lambert, Denis Lirette, and Ben Unsworth. Paperdude: A virtual reality cycling exergame. In *CHI '14 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '14, pages 475–478, New York, NY, USA, 2014. ACM.

[20] Margaret M Bradley and Peter J Lang. Measuring emotion: the self-assessment manikin and the semantic differential. *Journal of behavior therapy and experimental psychiatry*, 25(1):49–59, 1994.

[21] M. Brites-Pereira, M. J. Almeida, and A. Osório. Motion capture devices on elderly physical activities. In *2017 12th Iberian Conference on Information Systems and Technologies (CISTI)*, pages 1–4, June 2017.

[22] Jerome Seymour Bruner, Rose R Olver, Patricia M Greenfield, et al. *Studies in cognitive growth.* Wiley, 1966.

[23] Patrick Carrington, Amy Hurst, and Shaun K. Kane. Wearables and chairables: Inclusive design of mobile input and output techniques for power wheelchair users. In *Proceedings of the 32Nd Annual ACM Conference on Human Factors in Computing Systems*, CHI '14, pages 3103–3112, New York, NY, USA, 2014. ACM.

[24] Diana Carvalho, Maximino Bessa, Luís Magalhães, and Eurico Carrapatoso. Age group differences in performance using diverse input modalities: Insertion task evaluation. In *Proceedings of the XVII International Conference on Human Computer Interaction*, Interacción '16, pages 12:1–12:8, New York, NY, USA, 2016. ACM.

[25] M. J. Castro-Bleda, I. Bernabucci, M. Goffredo, E. Hassinen, B. Hollas, E. Lleida, A. Ortega, J. Pastor-Pellicer, and A. Salopuro. Collaborative learning in international teams on technologies to reduce the access barrier in human computer interaction (trabhci) erasmus intensive programme. In *2013 24th EAEEIE Annual Conference (EAEEIE 2013)*, pages 221–226, May 2013.

[26] Duo Chen, Joseph James, Forrest Sheng Bao, Chen Ling, and Tianzhe Fan. *Relationship Between Video Game Events and Player Emotion Based on EEG*, pages 377–384. Springer International Publishing, Cham, 2016.

[27] Weiqin Chen. Gesture-based applications for elderly people. In Masaaki Kurosu, editor, *Human-Computer Interaction. Interaction Modalities and Techniques*, pages 186–195, Berlin, Heidelberg, 2013. Springer Berlin Heidelberg.

[28] Dale Cox, Justin Wolford, Carlos Jensen, and Dedrie Beardsley. An evaluation of game controllers and tablets as controllers for interactive tv applications. In *Proceedings of the 14th ACM International Conference on Multimodal Interaction*, ICMI '12, pages 181–188, New York, NY, USA, 2012. ACM.

[29] Stefania Cuccurullo, Rita Francese, Sharefa Murad, Ignazio Passero, and Maurizio Tucci. A gestural approach to presentation exploiting motion capture metaphors. In *Proceedings of the International Working Conference on Advanced Visual Interfaces*, AVI '12, pages 148–155, New York, NY, USA, 2012. ACM.

[30] Ana Carla de Carvalho Correia, Leonardo Cunha de Miranda, and Heiko Hornung. Gesture-based interaction in domotic environments: State of the art and hci framework inspired by the diversity. In Paula Kotzé, Gary Marsden, Gitte Lindgaard, Janet Wesson, and Marco Winckler, editors, *Human-Computer Interaction – INTERACT 2013*, pages 300–317, Berlin, Heidelberg, 2013. Springer Berlin Heidelberg.

[31] Laurindo de Sousa Britto Neto, Vanessa Regina Margareth Lima Maike, Fernando Luiz Koch, Maria Cecília Calani Baranauskas, Anderson de Rezende Rocha, and Siome Klein Goldenstein. A wearable face recognition system built into a smartwatch and the blind and low vision users. In Slimane Hammoudi, Leszek Maciaszek, Ernest Teniente, Olivier Camp, and José Cordeiro, editors, *Enterprise Information Systems*, pages 515–528, Cham, 2015. Springer International Publishing.

[32] G. Deleuze and P. Patton. *Difference and Repetition*. Continuum Impacts Series. Bloomsbury Academic, 2004.

[33] Vlado Delić and Nataša Vujnović Sedlar. Stereo presentation and binaural localization in a memory game for the visually impaired. In *Development of Multimodal Interfaces: Active Listening and Synchrony*, pages 354–363. Springer, 2010.

[34] Denis Delimarschi, George Swartzendruber, and Huzefa Kagdi. Enabling integrated development environments with natural user interface interactions. In *Proceedings of the 22Nd International Conference on Program Comprehension*, ICPC 2014, pages 126–129, New York, NY, USA, 2014. ACM.

[35] Ines Di Loreto, Benoit Lange, Antoine Seilles, Sebastien Andary, and William Dyce. Game design for all: The example of hammer and planks. In Minhua Ma, Manuel Fradinho Oliveira, Sobah Petersen, and Jannicke Baalsrud Hauge, editors, *Serious Games Development and Applications*, pages 70–75, Berlin, Heidelberg, 2013. Springer Berlin Heidelberg.

[36] P. L. Emiliani and C. Stephanidis. Universal access to ambient intelligence environments: Opportunities and challenges for people with disabilities. *IBM Syst. J.*, 44(3):605–619, August 2005.

[37] Emotiv. *EPOC*, Accessed June 20th, 2018.

[38] Emre Ertin, Nathan Stohs, Santosh Kumar, Andrew Raij, Mustafa al'Absi, and Siddharth Shah. Autosense: Unobtrusively wearable sensor suite for inferring the onset, causality, and consequences of stress in the field. In *Proceedings of the 9th ACM Conference on Embedded Networked Sensor Systems*, SenSys '11, pages 274–287, New York, NY, USA, 2011. ACM.

[39] Raffaella Folgieri, Mattia G. Bergomi, and Simone Castellani. *EEG-Based Brain-Computer Interface for Emotional Involvement in Games Through Music*, pages 205–236. Springer New York, New York, NY, 2014.

[40] Raffaella Folgieri, Claudio Lucchiari, Marco Granato, and Daniele Grechi. *Brain, Technology and Creativity. BrainArt: A BCI-Based Entertainment Tool to Enact Creativity and Create Drawing from Cerebral Rhythms*, pages 65–97. Springer New York, New York, NY, 2014.

[41] Krista Francis, Steven Khan, and Brent Davis. Enactivism, spatial reasoning and coding. *Digital Experiences in Mathematics Education*, 2(1):1–20, Apr 2016.

[42] Mathias Frisch, Jens Heydekorn, and Raimund Dachselt. Diagram editing on interactive displays using multi-touch and pen gestures. In Ashok K. Goel, Mateja Jamnik, and N. Hari Narayanan, editors, *Diagrammatic Representation and Inference*, pages 182–196, Berlin, Heidelberg, 2010. Springer Berlin Heidelberg.

[43] Elizabeth Sucupira Furtado, Daniel Chagas, Ig Ibert Bittencourt, and Agebson Façanha. Acessibilidade e inclusão digital. *GranDIHC-BR – Grandes Desafios de Pesquisa em Interação Humano-Computador no Brasil*, pages 19–22, 2014.

[44] Elizabeth Sucupira Furtado, Guido Militão, Rossana Andrade, Leonardo Cunha Miranda, and Katia Oliveira. Ubiquidade, múltiplos dispositivos e tangibilidade. *GranDIHC-BR – Grandes Desafios de Pesquisa em Interação Humano-Computador no Brasil*, pages 23–26, 2014.

[45] Shaun Gallagher and Robb Lindgren. Enactive metaphors: Learning through full-body engagement. *Educational Psychology Review*, 27(3):391–404, Sep 2015.

[46] Tom Garner. Identifying habitual statistical features of eeg in response to fear-related stimuli in an audio-only computer video game. In *Proceedings of the 8th Audio Mostly Conference*, AM '13, pages 14:1–14:6, New York, NY, USA, 2013. ACM.

[47] Konstantinos Georgiadis, Herre Oostendorp, and Jelke Pal. Eeg assessment of surprise effects in serious games. In *Revised Selected Papers of the 4th International Conference on Games and Learning Alliance - Volume 9599*, GALA 2015, pages 517–529, New York, NY, USA, 2016. Springer-Verlag New York, Inc.

[48] Kathrin Gerling, Ian Livingston, Lennart Nacke, and Regan Mandryk. Full-body motion-based game interaction for older adults. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, pages 1873–1882, New York, NY, USA, 2012. ACM.

[49] Luc Geurts, Vero Vanden Abeele, Jelle Husson, Frederik Windey, Maarten Van Overveldt, Jan-Henk Annema, and Stef Desmet. Digital games for physical therapy: Fulfilling the need for calibration and adaptation. In *Proceedings of the Fifth International Conference on Tangible, Embedded, and Embodied Interaction*, TEI '11, pages 117–124, New York, NY, USA, 2011. ACM.

[50] James J Gibson. *The ecological approach to visual perception: classic edition*. Psychology Press, 2014.

[51] António Gomes, Hyunjoo Oh, Yoram Chisik, and Monchu Chen. Ilha musical: A cave for nurturing cultural appreciation. In *Proceedings of the 11th International Conference on Interaction Design and Children*, IDC '12, pages 232–235, New York, NY, USA, 2012. ACM.

[52] Javier Gómez, Germán Montoro, Pablo A. Haya, Xavier Alamán, Susana Alves, and Mónica Martínez. Adaptive manuals as assistive technology to support and train

people with acquired brain injury in their daily life activities. *Personal Ubiquitous Comput.*, 17(6):1117–1126, August 2013.

[53] Robert E Hall, B Bowerman, J Braverman, J Taylor, H Todosow, and U Von Wimmersperg. The vision of a smart city. Technical report, Brookhaven National Lab., Upton, NY (US), 2000.

[54] Julian Hamm, Arthur G. Money, Anita Atwal, and Ioannis Paraskevopoulos. Fall prevention intervention technologies: A conceptual framework and survey of the state of the art. *Journal of Biomedical Informatics*, 59:319 – 345, 2016.

[55] Anne-Wil Harzing et al. Publish or perish. 2007.

[56] Shih-Wen Hsiao, Chu-Hsuan Lee, Meng-Hua Yang, and Rong-Qi Chen. User interface based on natural interaction design for seniors. *Computers in Human Behavior*, 75:147 – 159, 2017.

[57] Susan Hwang, Adrian L. Jessup Schneider, Daniel Clarke, Alexander Macintosh, Lauren Switzer, Darcy Fehlings, and T.C. Nicholas Graham. How game balancing affects play: Player adaptation in an exergame for children with cerebral palsy. In *Proceedings of the 2017 Conference on Designing Interactive Systems*, DIS '17, pages 699–710, New York, NY, USA, 2017. ACM.

[58] Hiroshi Ishii and Brygg Ullmer. Tangible bits: Towards seamless interfaces between people, bits and atoms. In *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems*, pages 234–241. ACM, 1997.

[59] Jacek Jankowski and Stefan Decker. A dual-mode user interface for accessing 3d content on the world wide web. In *Proceedings of the 21st International Conference on World Wide Web*, WWW '12, pages 1047–1056, New York, NY, USA, 2012. ACM.

[60] Mauri Kaipainen, Niklas Ravaja, Pia Tikka, Rasmus Vuori, Roberto Pugliese, Marco Rapino, and Tapio Takala. Enactive systems and enactive media: Embodied human-machine coupling beyond interfaces. *Leonardo*, 44(5):433–438, 2011.

[61] André Luiz Satoshi Kawamoto and Valéria Farinazzo Martins. A visuospatial memory game for the elderly using gestural interface. In *International Conference on Universal Access in Human-Computer Interaction*, pages 430–443. Springer, 2017.

[62] D. F. Keefe and T. Isenberg. Reimagining the scientific visualization interaction paradigm. *Computer*, 46(5):51–57, May 2013.

[63] Florian Klompmaker, Volker Paelke, and Holger Fischer. A taxonomy-based approach towards nui interaction design. In Norbert Streitz and Constantine Stephanidis, editors, *Distributed, Ambient, and Pervasive Interactions*, pages 32–41, Berlin, Heidelberg, 2013. Springer Berlin Heidelberg.

[64] Hermann Kopetz. *Internet of Things*, pages 307–323. Springer US, Boston, MA, 2011.

[65] G. Kortuem, F. Kawsar, V. Sundramoorthy, and D. Fitton. Smart objects as building blocks for the internet of things. *IEEE Internet Computing*, 14(1):44–51, Jan 2010.

[66] Jonathan Lazar, Jinjuan Heidi Feng, and Harry Hochheiser. *Research Methods in Human-Computer Interaction*. Wiley Publishing, 2010.

[67] Rodger Lea and Michael Blackstock. Smart cities: An iot-centric approach. In *Proceedings of the 2014 International Workshop on Web Intelligence and Smart Sensing*, IWWISS '14, pages 12:1–12:2, New York, NY, USA, 2014. ACM.

[68] Alessandro Liberati, Douglas G Altman, Jennifer Tetzlaff, Cynthia Mulrow, Peter C Gøtzsche, John PA Ioannidis, Mike Clarke, Pl J Devereaux, Jos Kleijnen, and David Moher. The prisma statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS medicine*, 6(7):e1000100, 2009.

[69] G. Lightbody, L. Galway, and P. McCullagh. *The Brain Computer Interface: Barriers to Becoming Pervasive*, pages 101–129. Springer London, London, 2014.

[70] Shih-Yao Lin, Chuen-Kai Shie, Shen-Chi Chen, and Yi-Ping Hung. Airtouch panel: A re-anchorable virtual touch panel. In *Proceedings of the 21st ACM International Conference on Multimedia*, MM '13, pages 625–628, New York, NY, USA, 2013. ACM.

[71] Kecheng Liu. *Semiotics in Information Systems Engineering*. Cambridge University Press, New York, NY, USA, 2000.

[72] X Liu. Employing measur methods for process reengineering in china, 6 2001.

[73] Diego López-de Ipiña, Tania Lorido, and Unai López. Indoor navigation and product recognition for blind people assisted shopping. In José Bravo, Ramón Hervás, and Vladimir Villarreal, editors, *Ambient Assisted Living*, pages 33–40, Berlin, Heidelberg, 2011. Springer Berlin Heidelberg.

[74] R.L. Mace, G.J. Hardie, J.P. Place, and North Carolina State University. Center for Accessible Housing. *Accessible Environments: Toward Universal Design*. Center for Accessible Housing, North Carolina State University, 1990.

[75] I. Scott MacKenzie. *Human-Computer Interaction: An Empirical Research Perspective*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 1st edition, 2013.

[76] Vanessa R. M. L. Maike and M. Cecília C. Baranauskas. First steps in developing tangible artifacts for all: Enabling ideation and discussion processes. In Kecheng

Liu, Keiichi Nakata, Weizi Li, and Cecilia Baranauskas, editors, *Digitalisation, Innovation, and Transformation*, pages 238–247, Cham, 2018. Springer International Publishing.

[77] Vanessa R. M. L. Maike, Samuel B. Buchdid, and M. Cecília C. Baranauskas. Designing natural user interfaces scenarios for all and for some: An analysis informed by organizational semiotics artifacts. In Kecheng Liu, Keiichi Nakata, Weizi Li, and Daniel Galarreta, editors, *Information and Knowledge Management in Complex Systems*, pages 92–101, Cham, 2015. Springer International Publishing.

[78] Vanessa R. M. L. Maike, Samuel B. Buchdid, and M. Cecília C. Baranauskas. A smart supermarket must be for all: A case study including the visually impaired. In *Proceedings of the 15th Brazilian Symposium on Human Factors in Computing Systems*, IHC '16, pages 6:1–6:10, New York, NY, USA, 2016. ACM.

[79] Vanessa R. M. L. Maike, Julián Esteban Gutierrez Posada, and M. Cecília C. Baranauskas. A memory game for all: Differences and perception as a design strategy. To be published in the 17th Brazilian Symposium on Games and Digital Entertainment (SBGames 2018), 2018.

[80] Vanessa Regina Margareth Lima Maike, Laurindo de Sousa Britto Neto, Maria Cecília Calani Baranauskas, and Siome Klein Goldenstein. Seeing through the kinect: A survey on heuristics for building natural user interfaces environments. In Constantine Stephanidis and Margherita Antona, editors, *Universal Access in Human-Computer Interaction. Design and Development Methods for Universal Access*, pages 407–418, Cham, 2014. Springer International Publishing.

[81] Vanessa Regina Margareth Lima Maike, Laurindo de Sousa Britto Neto, Siome Klein Goldenstein, and Maria Cecília Calani Baranauskas. Heuristics for nui revisited and put into practice. In Masaaki Kurosu, editor, *Human-Computer Interaction: Interaction Technologies*, pages 317–328, Cham, 2015. Springer International Publishing.

[82] Vanessa RML Maike, Samuel Bastos Buchdid, Julián Esteban Gutierrez Posada, and M Cecília C Baranauskas. Bringing universal design and the web of things into the supermarket. *International Journal of Transitions and Innovation Systems*, 4(1-2):96–110, 2015.

[83] Alessio Malizia and Andrea Bellucci. The artificiality of natural user interfaces. *Commun. ACM*, 55(3):36–38, March 2012.

[84] S. Mann and M. Hrelja. Praxistemology: Early childhood education, engineering education in a university, and universal concepts for people of all ages and abilities. In *2013 IEEE International Symposium on Technology and Society (ISTAS): Social Implications of Wearable Computing and Augmediated Reality in Everyday Life*, pages 86–97, June 2013.

[85] Cristina Manresa-Yee, Maria Francesca Roig-Maimó, and Javier Varona. Mobile accessibility: natural user interface for motion-impaired users. *Universal Access in the Information Society*, Oct 2017.

[86] Cristina Manresa-Yee, Javier Varona, Francisco J. Perales, and Iosune Salinas. Design recommendations for camera-based head-controlled interfaces that replace the mouse for motion-impaired users. *Univers. Access Inf. Soc.*, 13(4):471–482, November 2014.

[87] Rytis Maskeliunas, Robertas Damasevicius, Ignas Martisius, and Mindaugas Vasiljevas. Consumer-grade eeg devices: are they usable for control tasks? *PeerJ*, 4:e1746, 2016.

[88] Lauren R. Milne, Cynthia L. Bennett, Richard E. Ladner, and Shiri Azenkot. Brailleplay: Educational smartphone games for blind children. In *Proceedings of the 16th International ACM SIGACCESS Conference on Computers & Accessibility*, ASSETS '14, pages 137–144, New York, NY, USA, 2014. ACM.

[89] Daniele Miorandi, Sabrina Sicari, Francesco De Pellegrini, and Imrich Chlamtac. Internet of things: Vision, applications and research challenges. *Ad Hoc Networks*, 10(7):1497 – 1516, 2012.

[90] Tony Morelli, John Foley, and Eelke Folmer. Vi-bowling: a tactile spatial exergame for individuals with visual impairments. In *Proceedings of the 12th international ACM SIGACCESS conference on Computers and accessibility*, pages 179–186. ACM, 2010.

[91] Larissa Müller, Sebastian Zagaria, Arne Bernin, Abbes Amira, Naeem Ramzan, Christos Grecos, and Florian Vogt. Emotionbike: A study of provoking emotions in cycling exergames. In Konstantinos Chorianopoulos, Monica Divitini, Jannicke Baalsrud Hauge, Letizia Jaccheri, and Rainer Malaka, editors, *Entertainment Computing - ICEC 2015*, pages 155–168, Cham, 2015. Springer International Publishing.

[92] Michael J. Muller, Jean Hallewell Haslwanter, and Tom Dayton. Chapter 11 - participatory practices in the software lifecycle. In Marting G. Helander, Thomas K. Landauer, and Prasad V. Prabhu, editors, *Handbook of Human-Computer Interaction (Second Edition)*, pages 255–297. North-Holland, Amsterdam, second edition edition, 1997.

[93] Taewoo Nam and Theresa A. Pardo. Conceptualizing smart city with dimensions of technology, people, and institutions. In *Proceedings of the 12th Annual International Digital Government Research Conference: Digital Government Innovation in Challenging Times*, dg.o '11, pages 282–291, New York, NY, USA, 2011. ACM.

[94] Karsten Nebe, Florian Klompmaker, Helge Jung, and Holger Fischer. Exploiting new interaction techniques for disaster control management using multitouch-, tangible- and pen-based-interaction. In Julie A. Jacko, editor, *Human-Computer*

Interaction. Interaction Techniques and Environments, pages 100–109, Berlin, Heidelberg, 2011. Springer Berlin Heidelberg.

[95] Neurosky. *Developer Documentation*, Accessed June 20th, 2018.

[96] Neurosky. *MindWave*, Accessed June 20th, 2018.

[97] Jakob Nielsen. *Usability engineering.* Elsevier, 1994.

[98] Donald A. Norman. Natural user interfaces are not natural. *interactions*, 17(3):6–10, May 2010.

[99] JongHwan Oh, Yerhyun Jung, Yongseok Cho, Chaewoon Hahm, Hyeyoung Sin, and Joonhwan Lee. Hands-up: Motion recognition using kinect and a ceiling to improve the convenience of human life. In *CHI '12 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '12, pages 1655–1660, New York, NY, USA, 2012. ACM.

[100] Kenton O'hara, Richard Harper, Helena Mentis, Abigail Sellen, and Alex Taylor. On the naturalness of touchless: Putting the “interaction” back into nui. *ACM Trans. Comput.-Hum. Interact.*, 20(1):5:1–5:25, April 2013.

[101] E. Oliveira, G. Sousa, T. A. Tavares, and P. Tanner. Sensory stimuli in gaming interaction: The potential of games in the intervention for children with cerebral palsy. In *2014 IEEE Games Media Entertainment*, pages 1–8, Oct 2014.

[102] O. A. Postolache and G. B. Postolache. Development and selection of balance sensing devices. *IEEE Instrumentation Measurement Magazine*, 20(1):38–48, February 2017.

[103] Roope Raisamo, Saija Patomäki, Matias Hasu, and Virpi Pasto. Design and evaluation of a tactile memory game for visually impaired children. *Interacting with Computers*, 19(2):196–205, March 2007.

[104] Manuela Renzi, Stavros Vassos, Tiziana Catarci, and Stephen Kimani. Touching notes: A gesture-based game for teaching music to children. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction*, TEI '15, pages 603–606, New York, NY, USA, 2015. ACM.

[105] Mitchel Resnick, John Maloney, Andrés Monroy-Hernández, Natalie Rusk, Evelyn Eastmond, Karen Brennan, Amon Millner, Eric Rosenbaum, Jay Silver, Brian Silverman, and Yasmin Kafai. Scratch: Programming for all. *Commun. ACM*, 52(11):60–67, November 2009.

[106] Kathryn E. Ringland, Rodrigo Zalapa, Megan Neal, Lizbeth Escobedo, Monica E. Tentori, and Gillian R. Hayes. Sensorypaint: A natural user interface supporting sensory integration in children with neurodevelopmental disorders. In *Proceedings of the Extended Abstracts of the 32Nd Annual ACM Conference on Human Factors in Computing Systems*, CHI EA '14, pages 1681–1686, New York, NY, USA, 2014. ACM.

[107] João M.F. Rodrigues, Joana Lessa, Miguel Gregório, Célia Ramos, and Pedro J. S. Cardoso. An initial framework for a museum application for senior citizens. In *Proceedings of the 7th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion*, DSAI 2016, pages 414–421, New York, NY, USA, 2016. ACM.

[108] James A Russell. A circumplex model of affect. *Journal of personality and social psychology*, 39(6):1161, 1980.

[109] Napa Sae-Bae, Kowsar Ahmed, Katherine Isbister, and Nasir Memon. Biometric-rich gestures: A novel approach to authentication on multi-touch devices. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, pages 977–986, New York, NY, USA, 2012. ACM.

[110] Jaime Sánchez, Mauricio Sáenz, and Miguel Ripoll. Usability of a multimodal videogame to improve navigation skills for blind children. In *Proceedings of the 11th International ACM SIGACCESS Conference on Computers and Accessibility*, ASSETS '09, pages 35–42, New York, NY, USA, 2009. ACM.

[111] Andrea Sanna, Fabrizio Lamberti, Gianluca Paravati, and Felipe Domingues Rocha. A kinect-based interface to animate virtual characters. *Journal on Multimodal User Interfaces*, 7(4):269–279, Dec 2013.

[112] Ânderson Schuh and Márcia de Borba Campos. Design of a decision-making task for a collaborative brain-computer interface system based on emotiv eeg. In Don Harris, editor, *Engineering Psychology and Cognitive Ergonomics: Cognition and Design*, pages 115–132, Cham, 2017. Springer International Publishing.

[113] Douglas Schuler and Aki Namioka. *Participatory Design: Principles and Practices.* CRC Press, 1993.

[114] A. Schulz, O. Arnold, and L. Kirsch. Smart districts in an ageing society. In *2014 IEEE 3rd Global Conference on Consumer Electronics (GCCE)*, pages 1–4, Oct 2014.

[115] Phoebe Sengers, Kirsten Boehner, Michael Mateas, and Geri Gay. The disenchantment of affect. *Personal and Ubiquitous Computing*, 12(5):347–358, Jun 2008.

[116] Feng-Ru Sheu and Nian-Shing Chen. Taking a signal: A review of gesture-based computing research in education. *Computers & Education*, 78:268 – 277, 2014.

[117] Mohd Fairuz Shiratuddin and Kok Wai Wong. *Game Design Considerations When Using Non-touch Based Natural User Interface*, pages 35–45. Springer Berlin Heidelberg, Berlin, Heidelberg, 2012.

[118] Ben Shneiderman. Universal usability. *Communications of the ACM*, 43(5):84–91, 2000.

[119] Paul Skalski, Ron Tamborini, Ashleigh Shelton, Michael Buncher, and Pete Lindmark. Mapping the road to fun: Natural video game controllers, presence, and game enjoyment. *New Media & Society*, 13(2):224–242, 2011.

[120] Tobias Sonne and Mads Møller Jensen. Chillfish: A respiration game for children with adhd. In *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction*, TEI '16, pages 271–278, New York, NY, USA, 2016. ACM.

[121] Betsy Sparrow, Jenny Liu, and Daniel M. Wegner. Google effects on memory: Cognitive consequences of having information at our fingertips. *Science*, 333(6043):776–778, 2011.

[122] Fotios Spyridonis, Tor-Morten Grønli, Ioannis Th. Paraskevopoulos, and Gheorghita Ghinea. A multi platform pain assessment tool using bespoke gaming sensors. In *Proceedings of the 9th ACM International Conference on PErvasive Technologies Related to Assistive Environments*, PETRA '16, pages 37:1–37:4, New York, NY, USA, 2016. ACM.

[123] Ronald K. Stamper. *Information in Business and Administrative Systems*. John Wiley & Sons, Inc., New York, NY, USA, 1973.

[124] Molly Follette Story, James L. Mueller, and Ronald L. Mace. *The Universal Design File: Designing for People of all Ages and Abilities*. ERIC, 1998.

[125] Alexandre G. Szykman, João Paulo Gois, and André Luiz Brandão. A perspective of games for people with physical disabilities. In *Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction*, OzCHI '15, pages 274–283, New York, NY, USA, 2015. ACM.

[126] B. Tabuenca, M. Kalz, and M. Specht. "tap it again, sam": Harmonizing the frontiers between digital and real worlds in education. In *2014 IEEE Frontiers in Education Conference (FIE) Proceedings*, pages 1–9, Oct 2014.

[127] Evan Thompson and Mog Stapleton. Making sense of sense-making: Reflections on enactive and extended mind theories. *Topoi*, 28(1):23–30, Mar 2009.

[128] Jelle van Dijk, Remko van der Lugt, and Caroline Hummels. Beyond distributed representation: Embodied cognition design supporting socio-sensorimotor couplings. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction*, TEI '14, pages 181–188, New York, NY, USA, 2013. ACM.

[129] Vero Vanden Abeele and Bob Schutter. Designing intergenerational play via enactive interaction, competition and acceleration. *Personal Ubiquitous Comput.*, 14(5):425–433, July 2010.

[130] Marijke Vandermaesen, Tom De Weyer, Peter Feys, Kris Luyten, and Karin Coninx. Integrating serious games and tangible objects for functional handgrip training: A

user study of handly in persons with multiple sclerosis. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, DIS '16, pages 924–935, New York, NY, USA, 2016. ACM.

[131] Samuel Bastos Buchdid Fabrício Matheus Gonçalves Maria Cecília Calani Baranauskas Vanessa Regina Margareth Lima Maike, Alysson Prado. A web das coisas em atividades do cotidiano: Explorando potenciais benefícios e desafios em um cenário social inclusivo. In *42º SEMISH - Seminário Integrado de Software e Hardware*, 2015.

[132] F.J. Varela, E. Thompson, E. Rosch, and J. Kabat-Zinn. *The Embodied Mind: Cognitive Science and Human Experience*. The Embodied Mind. MIT Press, 2017.

[133] Chen Wang, Pablo Cesar, and Erik Geelhoed. An invisible gorilla: Is it a matter of focus of attention? In Benoit Huet, Chong-Wah Ngo, Jinhui Tang, Zhi-Hua Zhou, Alexander G. Hauptmann, and Shuicheng Yan, editors, *Advances in Multimedia Information Processing – PCM 2013*, pages 318–326, Cham, 2013. Springer International Publishing.

[134] Mark Weiser. The computer for the 21st century. *Scientific american*, 265(3):94–104, 1991.

[135] E. Welbourne, L. Battle, G. Cole, K. Gould, K. Rector, S. Raymer, M. Balazinska, and G. Borriello. Building the internet of things using rfid: The rfid ecosystem experience. *IEEE Internet Computing*, 13(3):48–55, May 2009.

[136] Polly Welch. *Strategies for teaching universal design*. Mig Communications, 1995.

[137] Daniel Wigdor and Dennis Wixon. *Brave NUI World: Designing Natural User Interfaces for Touch and Gesture*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 1st edition, 2011.

[138] Pinata Winoto and Tiffany Y. Tang. Sensory substitution to enable the visually impaired to play an affordable wearable mobile game. In *Adjunct Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers*, UbiComp/ISWC'15 Adjunct, pages 193–196, New York, NY, USA, 2015. ACM.

[139] Jason Yang, Andrew Dekker, Ralf Muhlberger, and Stephen Viller. Exploring virtual representations of physical artefacts in a multi-touch clothing design collaboration system. In *Proceedings of the 21st Annual Conference of the Australian Computer-Human Interaction Special Interest Group: Design: Open 24/7*, OZCHI '09, pages 353–356, New York, NY, USA, 2009. ACM.

[140] Asım Evren Yantaç. A method for teaching affordance for user experience design in interactive media design education. In Aaron Marcus, editor, *Design, User Experience, and Usability. Design Philosophy, Methods, and Tools*, pages 630–638, Berlin, Heidelberg, 2013. Springer Berlin Heidelberg.

[141] Asım Evren Yantaç, Simge Esin Orhun, and Ayça Ünlüer Çimen. A challenging design case study for interactive media design education: Interactive media for individuals with autism. In Aaron Marcus, editor, *Design, User Experience, and Usability. User Experience Design Practice*, pages 185–196, Cham, 2014. Springer International Publishing.

[142] Bei Yuan and Eelke Folmer. Blind hero: Enabling guitar hero for the visually impaired. In *Proceedings of the 10th International ACM SIGACCESS Conference on Computers and Accessibility*, Assets '08, pages 169–176, New York, NY, USA, 2008. ACM.

[143] Deze Zeng, Song Guo, and Zixue Cheng. The web of things: A survey. *JCM*, 6(6):424–438, 2011.

Appendix A

Organizational Semiotics Artifacts Filled In

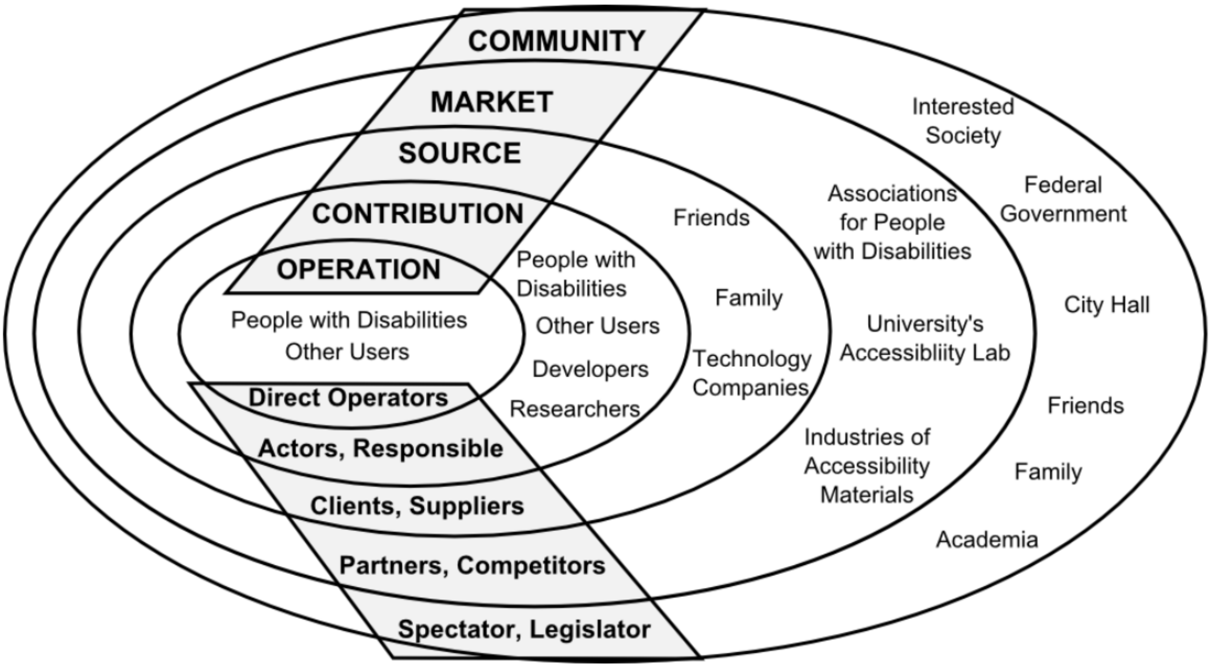


Figure A.1: Stakeholders Identification Diagram (SID)

STAKEHOLDERS	QUESTIONS & PROBLEMS	IDEAS & SOLUTIONS
OPERATION (Direct Operators)	- How efficient is the operation? - How comfortable does the user feel operating the device? - How does the user restart the device or takes back control after a problem?	- Operation time should not surpass the task time without the device. - Operations must not be uncomfortable. - Record the problem and restore system; also, provide a physical way to reset.
CONTRIBUTION (Actors, Reponsible)	- How do the users benefit from the device? - How do users report problems? - How do researchers and developers become aware of problems not reported by users?	- Devices will provide more autonomy to their users; also, Universal Design benefits people without disabilities. - Implement a log system and a direct communication channel with developers.
SOURCE (Customers, Suppliers)	- How can friends and family help the user to configure or learn to use the device? - How does the device affect interactions or relationships between user and friends/family?	- The device must be quick and easy to setup and configure by any person. - The device must not invade the privacy of people around the user.
MARKET (Partners, Competitors)	- How does the industry of accessibility materials benefit from the devices and technology created? - How does the associations for people with disabilities and the University's Accessibility Lab benefit from the devices and technology created? - How does the device impact NUI devices companies?	- Transforming tested devices into commercial products. - Associations and the Accessibility Lab can use the prototypes and, later, the finished final products (hopefully made by the industry). - Devices and technologies must be patented to protect and share intellectual property.
COMMUNITY (Spectator, Legislator)	- How can the Government help in the dissemination of the devices? - How does Government Regulation adapt? - How can academia benefit from the devices? - How can friends/family benefit from the devices? - How does the user deal with battery discharge?	- By distributing devices in communities. - Regulation must protect the interests and integrity of users and those around them. - Discoveries made during design process can instigate new or ongoing researches. - The device must inform battery status and provide warnings when it is close to empty.

Figure A.2: Evaluation Frame (EF)

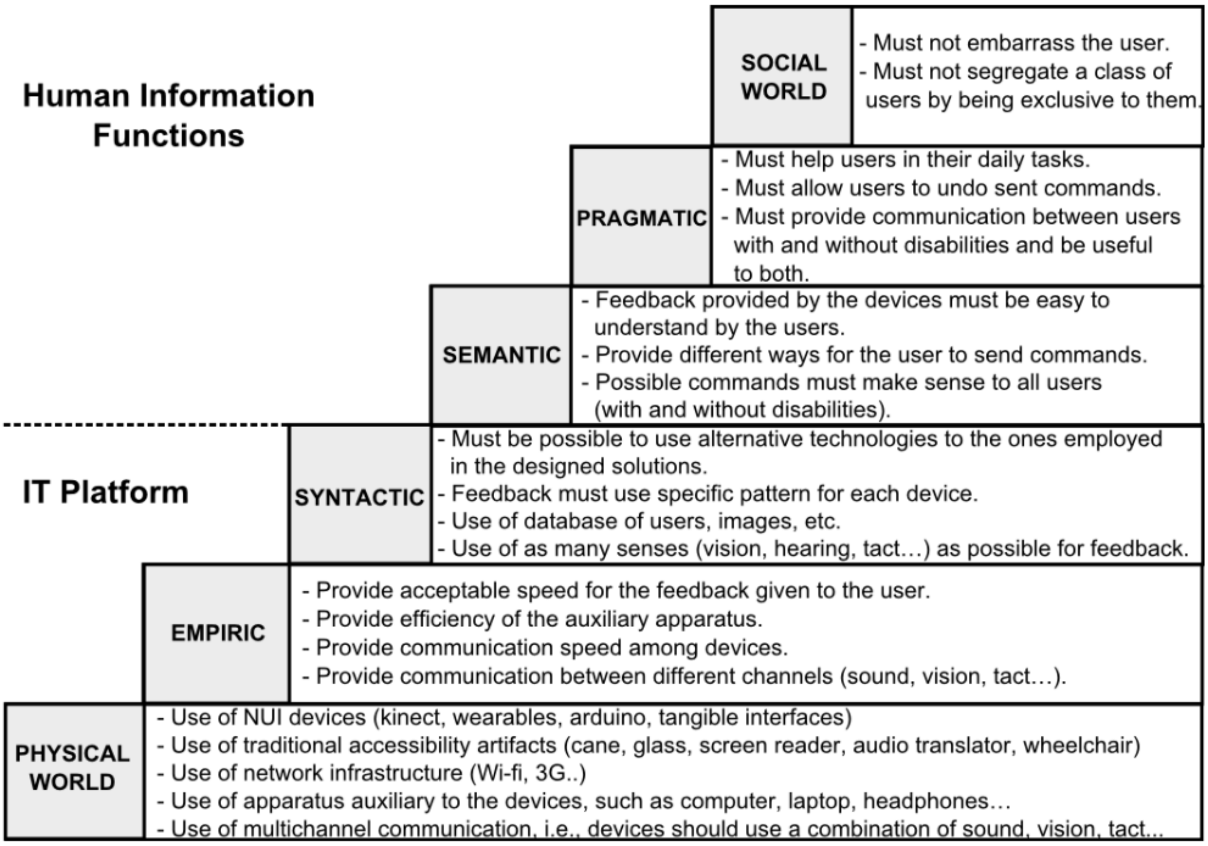


Figure A.3: Semiotic Framework (SF)

Appendix B

Original NUI Heuristics

Following, is the first set of 23 heuristics, with the corresponding references that originated them, as published in [80].

INTERACTION
1. **Operation modes:** provide different operation modes, each with its own primary information carrier (e.g., text, hypertext, multimedia. . .).. Also, provide an explicit way for the user to switch between modes and offer a smooth transition. [51, 59, 139]
2. **"Interactability":** selectable and/or "interactable" objects should be explicit and allow both their temporary and permanent selection. [11, 28, 59]
3. **Accuracy:** input by the user (e.g., gestures) should be accurately detected and tracked. [51, 29, 94, 99, 117]
4. **Responsiveness:** the execution of the user input should be in real time. [28, 29, 94]
5. **Identity:** sets of interaction metaphors should make sense as whole, so that it is possible to understand what the system can and cannot interpret. When applicable, visual grouping of semantic similar commands should be made. [11]
6. **Metaphor coherence:** interaction metaphors should have a clear relationship with the functionalities they execute, requiring a reduced mental load. [28, 29]
7. **Distinction:** interaction metaphors should not be too similar, to avoid confusion and facilitate recognition. [117]
8. **Comfort:** the interaction should not require much effort and should not cause fatigue on the user. [11, 28, 29, 38, 70, 111]
9. **Device-Task compatibility:** the tasks for which the NUI device is going to be used have to be compatible with the kind of interaction it offers (e.g., using the Kinect as a mouse cursor is inadequate). [28, 117, 139]

NAVIGATION
10. **Guidance:** there has to be a balance between exploration and guidance, to maintain a flow of interaction both to expert and novice users. Also, shortcuts should be provided for expert users. [11, 42, 59, 111]
11. **Wayfinding:** users should be able to know where they are from a big picture perspective and from a microscopic perception. [59, 111]
12. **Active Exploration:** to promote the learning of a large set of interaction metaphors, a difficult task, active exploration of this set should be favored to enhance transition from novice to expert usage. [11, 17]
13. **Space:** the location in which the system is expected to be used must be appropriate for the kinds of interactions it requires (e.g., full body gestures require a lot of space) and for the number of simultaneous users. [51, 117]

USER ADOPTION
14. **Engagement:** provide immersion during the interaction, at the same time allowing for easy information acquiring and integration. [51, 59]
15. **Competition:** in comparison with the equivalent interactions from traditional non-NUI interfaces, the NUI alternative should be more efficient, more engaging and easier to use. [109, 111, 117]
16. **Affordability:** the NUI device should have an affordable cost. [111]
17. **Familiarity:** the interface should provide a sense of familiarity, which is also related to the coherence between task and device and between interaction metaphor and functionality. [11, 28, 94]
18. **Social acceptance:** using the device should not cause embarrassment to the users. [28, 38, 117]
19. **Learnability:** there has to be coherence between learning time and frequency of use; if the task is performed frequently (such as in a working context), then it is acceptable to have some learning time; otherwise, the interface should be usable without learning. [17, 63, 117]

MULTIPLE USERS
20. **Conflict:** if the system supports multiple users working in the same task at the same time, then it should handle and prevent conflicting inputs. [1, 2, 8, 10, 13, 19]
21. **Parallel processing:** enable personal views so that users can each work on their parallel tasks without interfering with the group view. [2, 13]
22. **Two-way communication:** if multiple users are working on different activities through the same interface, and are not necessarily in the same room, provide ways for both sides to communicate with each other. [21]
23. **Learning:** when working together, users learn from each other by copying, so it is important to allow them to be aware of each other's actions and intentions. [2]

Appendix C

Forms for Using the NUI Heuristics (English and Portuguese)

Heuristics for the Design and Evaluation of Natural User Interface (NUI)

[NH1] Operation Modes The system must provide different operation modes (visual, auditory, tactile, gestural, voice-based, etc.). In addition, the system must provide an explicit way for the user to switch between the modes, offering a smooth transition.
Rationale
Non-compliant ... Compliant -4 -3 -2 -1 0 1 2 3 4
[NH2] "Interactability" In the system, the selectable and the "interactable" objects should be explicit and allow both their temporary and permanent selection.
Rationale
Non-compliant ... Compliant -4 -3 -2 -1 0 1 2 3 4
[NH3] Metaphor Adequacy The sets of interaction metaphors the system provides should make sense as a whole, so that it is possible to understand what the system can and cannot interpret. When applicable, there should be a visual grouping of semantic similar commands. In addition, the interaction metaphors should have a clear relationship with the functionalities they execute, requiring from the user a reduced mental load and providing a sense of familiarity. Finally, the metaphors should not be too similar to one another, to avoid confusion and facilitate recognition.
Rationale
Non-compliant ... Compliant -4 -3 -2 -1 0 1 2 3 4

[NH4] Learnability
There has to be coherence between learning time and frequency of use. Therefore, if the task is performed frequently then it is acceptable to require some learning time; otherwise, the interface should be usable without much learning effort. In addition, the design must consider that users learn from each other by copying when they work together, so it is important to allow them to be aware of each other's actions and intentions.
Rationale
Non-compliant -4 -3 -2 -1 0 1 2 3 4 Compliant

[NH5] Guidance Balance
There has to be a balance between exploration and guidance, to maintain a flow of interaction to both the expert and the novice users. To enhance transition from novice to expert usage, active exploration of the set of interaction metaphors should be encouraged by the system. Finally, it is important to provide shortcuts for the expert users.
Rationale
Non-compliant -4 -3 -2 -1 0 1 2 3 4 Compliant

[NH6] Wayfinding
At any time, users should be able to know where they are from a big picture perspective and from a microscopic perception. This is important regardless of user proficiency with the system, i.e., novice and expert users need both views of the system.
Rationale
Non-compliant -4 -3 -2 -1 0 1 2 3 4 Compliant

[NH7] Comfort Interacting with the system should not require much effort from the user and should not cause fatigue.
Rationale
Non-compliant Compliant -4 -3 -2 -1 0 1 2 3 4

[NH8] Space The location where the system is expected to be used must be appropriate for the kinds of interactions it requires and for the number of simultaneous users it supports.
Rationale
Non-compliant Compliant -4 -3 -2 -1 0 1 2 3 4

[NH9] Engagement The system should provide immersion during the interaction, at the same time allowing for easy information acquiring and integration.
Rationale
Non-compliant Compliant -4 -3 -2 -1 0 1 2 3 4

[NH10] Device-Task Compatibility
The system has to offer kinds of interactions that are compatible with the task for which it is going to be used.
Rationale
Non-compliant -4 -3 -2 -1 0 1 2 3 4 Compliant

[NH11] Social Acceptance
Using the system should not cause embarrassment to the users.
Rationale
Non-compliant -4 -3 -2 -1 0 1 2 3 4 Compliant

[NH12] Awareness of Others
If the system supports multiple users working in the same task at the same time, then it should handle and prevent conflicting inputs. Therefore, users must be able to work in parallel without disturbing each other, but having awareness of the others.
Rationale
Non-compliant -4 -3 -2 -1 0 1 2 3 4 Compliant

[NH13] Two-way Communication
If multiple users are working on different activities through the same interface, and are not necessarily in the same vicinity, the system must provide ways for both sides to communicate with each other.
Rationale
Non-compliant -4 -3 -2 -1 0 1 2 3 4 Compliant

Heurísticas para Design e Avaliação de Natural User Interface (NUI)

[NH1] Modos de Operação O sistema deve prover diferentes modos de operação (visual, auditivo, táctil, gestual, baseado em voz, etc.). Além disso, o sistema deve prover um mecanismo explícito para o usuário trocar entre os modos, oferecendo uma transição suave.
Análise
Não conformidade … Em conformidade -4 -3 -2 -1 0 1 2 3 4

[NH2] "Interactabilidade" No sistema, os objetos selecionáveis e os "interagíveis" devem ser explícitos e permitir tanto sua seleção temporária quanto permanente.
Análise
Não conformidade … Em conformidade -4 -3 -2 -1 0 1 2 3 4

[NH3] Adequação de Metáfora Os conjuntos de metáforas de interação que o sistema provê precisam fazer sentido como um todo, para que seja possível entender o que o sistema consegue ou não interpretar. Quando aplicável, deve haver um agrupamento visual de comandos semanticamente semelhantes. Além disso, as metáforas de interação devem ter uma relação clara com as funcionalidades que executam, requerendo do usuário uma carga mental reduzida e provendo um senso de familiaridade. Por fim, as metáforas não devem ser muito semelhantes entre si, para evitar confusão e facilitar o reconhecimento.
Análise
Não conformidade … Em conformidade -4 -3 -2 -1 0 1 2 3 4

[NH4] Aprendizibilidade

Deve haver coerência entre o tempo de aprendizado e a frequência de uso. Portanto, se a tarefa é realizada frequentemente, então é aceitável requerer algum tempo de aprendizado; caso contrário, a interface deve ser usável sem muito esforço de aprendizado. Além disso, o design deve considerar que usuários aprendem uns com os outros, copiando, quando trabalham juntos, então é importante permitir que estejam cientes das ações e intenções uns dos outros.

Análise

Não conformidade — Em conformidade

-4 -3 -2 -1 0 1 2 3 4

[NH5] Equilíbrio de Orientação

Deve haver equilíbrio entre exploração e orientação, para manter o fluxo de interação tanto para os usuários experts quanto para os novatos. Para melhorar a transição do uso novato para o uso expert, o sistema deve encorajar a exploração ativa do conjunto de metáforas de interação. Por fim, é importante prover atalhos para usuários experts.

Análise

Não conformidade — Em conformidade

-4 -3 -2 -1 0 1 2 3 4

[NH6] Navegação

A qualquer momento, usuários devem ser capazes de saber aonde estão, tanto da perspectiva do todo, quanto da microscópica. Isto é importante independente de proficiência do usuário com o sistema, i.e., usuários novatos e experts precisam de ambas as visões do sistema.

Análise

Não conformidade — Em conformidade

-4 -3 -2 -1 0 1 2 3 4

[NH7] Conforto
Interagir com o sistema não deve requerer muito esforço do usuário e não deve causar fadiga.
Análise
Não conformidade -4 -3 -2 -1 0 1 2 3 4 Em conformidade

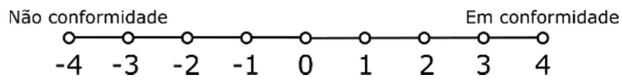
[NH8] Espaço
O local onde espera-se que o sistema seja utilizado deve ser apropriado para os tipos de interação que ele requer, e para o número de usuários simultâneos que ele suporta.
Análise
Não conformidade -4 -3 -2 -1 0 1 2 3 4 Em conformidade

[NH9] Engajamento
O sistema deve prover imersão durante a interação, e ao mesmo tempo permitir fácil aquisição e integração da informação.
Análise
Não conformidade -4 -3 -2 -1 0 1 2 3 4 Em conformidade

[NH10] Compatibilidade Dispositivo-Tarefa
O sistema deve oferecer tipos de interação que sejam compatíveis com a tarefa na qual ele será utilizado.
Análise
Não conformidade — Em conformidade -4 -3 -2 -1 0 1 2 3 4

[NH11] Aceitação Social
Usar o sistema não deve causar constrangimento aos usuários.
Análise
Não conformidade — Em conformidade -4 -3 -2 -1 0 1 2 3 4

[NH12] Consciência de Outros
Se o sistema suportar diversos usuários trabalhando na mesma tarefa ao mesmo tempo, então ele deve lidar com e prevenir conflitos de entrada. Portanto, usuários devem ser capazes de trabalhar em paralelo sem atrapalhar uns aos outros, mas tendo consciência dos demais.
Análise
Não conformidade — Em conformidade -4 -3 -2 -1 0 1 2 3 4

[NH13] Comunicação de Duas Vias
Se múltiplos usuários estão trabalhando em atividades diferentes pela mesma interface, e não estão necessariamente em proximidade, o sistema deve prover formas para ambos os lados se comunicarem entre si.
Análise


Appendix D

Ethics Committee Documentation

FACULDADE DE CIENCIAS
MEDICAS - UNICAMP
(CAMPUS CAMPINAS)

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Investigando Natural User Interfaces (NUIs) - Tecnologias e Interação em Contexto de Acessibilidade

Pesquisador: Vanessa Regina Margareth Lima Maike

Área Temática:

Versão: 1

CAAE: 31818014.0.0000.5404

Instituição Proponente: Instituto de Computação

Patrocinador Principal: Universidade Estadual de Campinas - UNICAMP

DADOS DO PARECER

Número do Parecer: 709.828

Data da Relatoria: 24/06/2014

Apresentação do Projeto:

Trata-se de um projeto de pesquisa, no âmbito de uma tese de doutorado, que visa estudar, analisar, implementar e avaliar tecnologias que utilizam interfaces naturais (NUIs) para aumentar a acessibilidade. A pesquisadora pretende implementar tecnologias assistivas (como um capacete usando a tecnologia Kinect) para aumentar a interatividade de portadores de doença visual. Os testes serão realizados no Instituto de Computação (IC) da Unicamp. Serão utilizados 30 voluntários de pesquisa (20 usuários sem deficiência e 10 usuários com deficiência). O projeto conta com financiamento através de uma bolsa de doutorado da CAPES, e tem início previsto de avaliação das tecnologias desenvolvidas em 01/2015.

Objetivo da Pesquisa:

Propor melhores maneiras de construir tecnologias com interfaces naturais – Natural User Interfaces (NUIs) – no contexto de acessibilidade. Como sub-objetivos estão o design e a avaliação, dentro do contexto de acessibilidade, de novas tecnologias que também pertençam ao paradigma NUI.

Avaliação dos Riscos e Benefícios:

A pesquisadora descreve que não há riscos previsíveis durante os testes com os usuários. Quanto aos benefícios diretos aos voluntários, a pesquisa prevê que os mesmos possam aprender a

Endereço: Rua Tessália Vieira de Camargo, 126
Bairro: Barão Geraldo **CEP:** 13.083-887
UF: SP **Município:** CAMPINAS
Telefone: (19)3521-8936 **Fax:** (19)3521-7187 **E-mail:** cep@fcm.unicamp.br

utilizar tecnologias digitais que não fazem parte do seu cotidiano.

Comentários e Considerações sobre a Pesquisa:

Considero a pesquisa interessante e valida para aplicação em seres humanos. Os resultados podem ter uma alta relevância na área de tecnologias assistivas. O projeto também é claro e sucinto.

Considerações sobre os Termos de apresentação obrigatória:

Foram apresentados: 1) projeto de pesquisa detalhado; 2) folha de rosto, devidamente preenchida, datada e assinada pelo diretor associado do Instituto de Comunicação/UNICAMP, (instituição proponente); 3) termo de consentimento livre e esclarecido (TCLE), no modelo proposto pelo CEP/UNICAMP, de acordo com a Res. CNS-MS 466/12.

Recomendações:

Conclusões ou Pendências e Lista de Inadequações:

Documentos de acordo com a Res. CNS-MS 466/12. Os objetivos e a metodologia com os voluntários é clara. Considero o projeto aprovado.

Projeto aprovado em reunião do colegiado, em 24-06-2014.

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

Considerações Finais a critério do CEP:

- Se o TCLE tiver mais de uma página, o sujeito de pesquisa ou seu representante, quando for o caso, e o pesquisador responsável deverão rubricar todas as folhas desse documento, apondo suas assinaturas na última página do referido termo (Carta Circular nº 003/2011/CONEP/CNS).

- Cabe ao pesquisador desenvolver a pesquisa conforme delineada no protocolo aprovado, elaborar e apresentar os relatórios parciais e final, bem como encaminhar os resultados para publicação com os devidos créditos aos pesquisadores associados e ao pessoal técnico participante do projeto (Resolução 466/2012 CNS/MS). Os relatórios deverão ser enviados através da Plataforma Brasil- ícone Notificação.

- Eventuais modificações ou emendas ao protocolo deverão ser apresentadas ao CEP de forma

Endereço: Rua Tessália Vieira de Camargo, 126
Bairro: Barão Geraldo **CEP:** 13.083-887
UF: SP **Município:** CAMPINAS
Telefone: (19)3521-8936 **Fax:** (19)3521-7187 **E-mail:** cep@fcm.unicamp.br

clara e sucinta, identificando a parte do protocolo a ser modificada (com destaque) e suas justificativas. As modificações deverão ter parecer de aprovação deste CEP antes de serem implementadas.

CAMPINAS, 05 de Julho de 2014

Assinado por:
Fátima Aparecida Bottcher Luiz
(Coordenador)

Endereço: Rua Tessália Vieira de Camargo, 126
Bairro: Barão Geraldo **CEP:** 13.083-887
UF: SP **Município:** CAMPINAS
Telefone: (19)3521-8936 **Fax:** (19)3521-7187 **E-mail:** cep@fcm.unicamp.br

pró visão

SOCIEDADE CAMPINEIRA DE ATENDIMENTO AO DEFICIENTE VISUAL

Autorização para coleta de dados

Eu, **Profª Drª Maria Cristina von Zuben de Arruda Camargo,** Presidente da **Pró-Visão Sociedade Campineira de Atendimento ao Deficiente Visual**, declaro estar ciente dos requisitos da Resolução CNS/MS 466/12 e suas complementares e que tenho conhecimento dos procedimentos/instrumentos aos quais os participantes da presente pesquisa serão submetidos. Assim autorizo a coleta de dados do projeto de pesquisa intitulado **"Investigando Natural User Interfaces (NUIs) - Tecnologias e Interação em Contexto de Acessibilidade"**, sob responsabilidade do(a) pesquisador(a) **Vanessa Regina Margareth Lima Maike** após a aprovação do referido projeto de pesquisa pelo Comitê de Ética em Pesquisa-Unicamp.

Profª Drª Maria Cristina von Zuben de Arruda Camargo

Data: 30/07/2015

Pró-Visão - Sociedade Campineira de Atendimento ao Deficiente Visual
Avenida Antônio Carlos Sales Júnior, 580 – Jardim Proença
CEP 13.100-410 – Campinas – SP - Fone: (19) 3254-4648 / Fax: (19) 3255-3455
CNPJ 51.917.995/0001-90 Inscrição Estadual: isenta
E-mail: provisao@provisao.org.br Site: www.provisao.org.br

PARECER CONSUBSTANCIADO DO CEP

DADOS DA EMENDA

Título da Pesquisa: Investigando Natural User Interfaces (NUIs) - Tecnologias e Interação em Contexto de Acessibilidade

Pesquisador: Vanessa Regina Margareth Lima Maike

Área Temática:

Versão: 4

CAAE: 31818014.0.0000.5404

Instituição Proponente: Instituto de Computação

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 1.720.700

Apresentação do Projeto:

Trata-se de uma emenda ao projeto original, adicionado uma instituição coparticipante para fins de coleta de dados. Como essa instituição atende pessoas menores de idade, encaminhou-se também o TCLE para ser obtido nesses casos.

Objetivo da Pesquisa:

Objetivo Primário:

O objetivo principal deste projeto é propor melhores maneiras de construir tecnologias com interfaces naturais – Natural User Interfaces (NUIs) – no contexto de acessibilidade.Como sub-objetivos estão o design e a avaliação, dentro do contexto de acessibilidade, de novas tecnologias que também pertençam ao paradigma NUI.

Objetivo Secundário:

1) Investigar, no contexto de acessibilidade, a interação de usuários (com e sem deficiência) com tecnologias já existentes e que utilizam NUI;2) Propor, especificar e experimentar cenários de uso de tecnologias adequadas ao contexto de acessibilidade.

Avaliação dos Riscos e Benefícios:
Os riscos e benefícios se mantiveram os mesmos do projeto original.

Comentários e Considerações sobre a Pesquisa:
Apresentou-se uma emenda com o objetivo de incluir uma instituição coparticipante que é a Pró-Visão. Também foi enviada o TCLE que será obtido dos participantes menores de idade.

Considerações sobre os Termos de apresentação obrigatória:
Na presente emenda foram anexados os seguintes documentos: a) Informações básicas do projeto; b) Projeto de pesquisa completo; c) Termos de Consentimento Livre e Esclarecido (um participantes maiores de idade e outro para os menores de idade/representante legal).

Recomendações:
Nenhuma.

Conclusões ou Pendências e Lista de Inadequações:
1. Especificar no projeto a idade dos menores que serão convidados a participar da pesquisa.
RESPOSTA: Acrescentou-se no projeto de pesquisa que "... dos participantes que são atendidos pela Pró-Visão, que não possui restrições de faixa etária".
ANÁLISE: PENDÊNCIA ATENDIDA

2. Como a pesquisa irá incluir menores de idade, deve ser preparado um TCLE específico para essa categoria de participante. O conteúdo do TCLE será o mesmo, no entanto a redação deve mudar já que quem está sendo convidado é o(a) filho(a) da pessoa. Na redação do TCLE, ao invés de dizer "você", deve estar escrito "seu(sua) filho(a). Além disso, no início do TCLE, na primeira linha deve ser adicionado uma linha para que o pai/representante legal escreva o nome do menor de idade como por exemplo "Seu(sua) filho(a) __________ está sendo convidado...".
RESPOSTA: A pesquisadora anexou um TCLE para menores de idade que será assinada tanto pelos representante legal como pelos adolescentes com 14 ou mais. No final do termo, foi acrescentada uma linha para inserir o nome do menor de idade.
ANÁLISE: PENDÊNCIA ATENDIDA

Endereço: Rua Tessália Vieira de Camargo, 126
Bairro: Barão Geraldo **CEP:** 13.083-887
UF: SP **Município:** CAMPINAS
Telefone: (19)3521-8936 **Fax:** (19)3521-7187 **E-mail:** cep@fcm.unicamp.br

3. Os menores com 14 anos ou mais devem assinar o TCLE juntamente com os pais/representante legal. Para isso é necessário adicionar uma linha abaixo da linha onde o pai/representante legal irá assinar para que o adolescente também assine o TCLE.
RESPOSTA: A pesquisadora adicionou uma linha no final do TCLE para que os menores de 14 anos possam assinar o termo em conjunto com seu representante legal.
ANÁLISE: PENDÊNCIA ATENDIDA

Considerações Finais a critério do CEP:
- O sujeito de pesquisa deve receber uma via do Termo de Consentimento Livre e Esclarecido, na íntegra, por ele assinado (quando aplicável).

- O sujeito da pesquisa tem a liberdade de recusar-se a participar ou de retirar seu consentimento em qualquer fase da pesquisa, sem penalização alguma e sem prejuízo ao seu cuidado (quando aplicável).

- O pesquisador deve desenvolver a pesquisa conforme delineada no protocolo aprovado. Se o pesquisador considerar a descontinuação do estudo, esta deve ser justificada e somente ser realizada após análise das razões da descontinuidade pelo CEP que o aprovou. O pesquisador deve aguardar o parecer do CEP quanto à descontinuação, exceto quando perceber risco ou dano não previsto ao sujeito participante ou quando constatar a superioridade de uma estratégia diagnóstica ou terapêutica oferecida a um dos grupos da pesquisa, isto é, somente em caso de necessidade de ação imediata com intuito de proteger os participantes.

- O CEP deve ser informado de todos os efeitos adversos ou fatos relevantes que alterem o curso normal do estudo. É papel do pesquisador assegurar medidas imediatas adequadas frente a evento adverso grave ocorrido (mesmo que tenha sido em outro centro) e enviar notificação ao CEP e à Agência Nacional de Vigilância Sanitária – ANVISA – junto com seu posicionamento.

- Eventuais modificações ou emendas ao protocolo devem ser apresentadas ao CEP de forma clara e sucinta, identificando a parte do protocolo a ser modificada e suas justificativas e aguardando a aprovação do CEP para continuidade da pesquisa. Em caso de projetos do Grupo I ou II

Endereço: Rua Tessália Vieira de Camargo, 126
Bairro: Barão Geraldo **CEP:** 13.083-887
UF: SP **Município:** CAMPINAS
Telefone: (19)3521-8936 **Fax:** (19)3521-7187 **E-mail:** cep@fcm.unicamp.br

apresentados anteriormente à ANVISA, o pesquisador ou patrocinador deve enviá-las também à mesma, junto com o parecer aprovatório do CEP, para serem juntadas ao protocolo inicial.

- Relatórios parciais e final devem ser apresentados ao CEP, inicialmente seis meses após a data deste parecer de aprovação e ao término do estudo.

-Lembramos que segundo a Resolução 466/2012 , item XI.2 letra e, “cabe ao pesquisador apresentar dados solicitados pelo CEP ou pela CONEP a qualquer momento”.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_560918_E1.pdf	10/07/2016 22:37:26		Aceito
Projeto Detalhado / Brochura Investigador	ProjetoPesquisa_VanessaMaike_v4_EMENDA.pdf	10/07/2016 22:35:12	Vanessa Regina Margareth Lima Maike	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE_VanessaMaike_Emenda_v3_MAIORES.pdf	10/07/2016 22:32:55	Vanessa Regina Margareth Lima Maike	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE_VanessaMaike_Emenda_v3_MENORES.pdf	10/07/2016 22:32:39	Vanessa Regina Margareth Lima Maike	Aceito
Folha de Rosto	folhaderosto_assinada.pdf	22/01/2016 14:25:57	Vanessa Regina Margareth Lima Maike	Aceito
Outros	provisaoCEP.pdf	18/01/2016 11:06:51	Vanessa Regina Margareth Lima Maike	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

Endereço: Rua Tessália Vieira de Camargo, 126
Bairro: Barão Geraldo **CEP:** 13.083-887
UF: SP **Município:** CAMPINAS
Telefone: (19)3521-8936 **Fax:** (19)3521-7187 **E-mail:** cep@fcm.unicamp.br

COMITÊ DE ÉTICA EM PESQUISA DA UNICAMP - CAMPUS CAMPINAS

Continuação do Parecer: 1.720.700

CAMPINAS, 12 de Setembro de 2016

Assinado por:
Renata Maria dos Santos Celeghini
(Coordenador)

Endereço: Rua Tessália Vieira de Camargo, 126
Bairro: Barão Geraldo **CEP:** 13.083-887
UF: SP **Município:** CAMPINAS
Telefone: (19)3521-8936 **Fax:** (19)3521-7187 **E-mail:** cep@fcm.unicamp.br

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Investigando Natural User Interfaces (NUIs) – Tecnologias e Interação em Contexto de Acessibilidade
Vanessa Regina Margareth Lima Maike e Maria Cecília Calani Baranauskas
Número do CAAE: 31818014.0.0000.5404

Você está sendo convidado a participar como voluntário de um estudo. Este documento, chamado Termo de Consentimento Livre e Esclarecido, visa assegurar seus direitos como participante e é elaborado em duas vias, uma que deverá ficar com você e outra com o pesquisador.

Por favor, leia com atenção e calma, aproveitando para esclarecer suas dúvidas. Se houver perguntas antes ou mesmo depois de assiná-lo, você poderá esclarecê-las com o pesquisador. Se preferir, pode levar para casa e consultar seus familiares ou outras pessoas antes de decidir participar. Se você não quiser participar ou retirar sua autorização, a qualquer momento, não haverá nenhum tipo de penalização ou prejuízo.

Justificativa e objetivos:

Desde que os computadores foram criados, foi crescente não apenas a sua evolução, como também a sua presença na vida e no cotidiano das pessoas. Nos últimos anos, essa evolução levou a um novo paradigma de interação entre usuários e tecnologia, conhecido como Natural User Interfaces (NUIs), ou interfaces naturais. Esse novo paradigma promete reduzir ainda mais as barreiras entre a máquina e as pessoas e, ao mesmo tempo, dar mais poder ao usuário. Entretanto, é importante ressaltar que a força das interfaces naturais está presa a três elementos: aos contextos nos quais se encaixam, às maneiras como moldam a interação das pessoas com a tecnologia e aos tipos de tarefas que facilitam.

Pensando no cenário descrito, o objetivo principal deste projeto é propor melhores maneiras de construir tecnologias com interfaces naturais, no contexto de acessibilidade. Como objetivos secundários estão o design e a avaliação, dentro do contexto de acessibilidade, de novas tecnologias que também pertençam ao paradigma NUI.

Portanto, ao investigar diferentes tecnologias com NUIs em um contexto prático específico, com usuários reais e na realização de tarefas específicas, este projeto de pesquisa terá como consequência direta o fortalecimento das interfaces naturais não apenas como campo de pesquisa, mas como forma de interação em diferentes tecnologias.

O estudo de tecnologias com NUIs no contexto de acessibilidade também deve trazer benefícios para seus usuários, especialmente aqueles com deficiência. Além de possibilitar que esse grupo de usuários utilize uma gama maior de dispositivos, espera-se também uma melhoria nos tipos de usos que eles conseguirão fazer das tecnologias com NUIs à sua disposição.

Procedimentos:

Participando do estudo você está sendo convidado a:

- Realizar o teste de um ou mais sistemas computacionais que utilizem interfaces naturais. O teste consiste na utilização desses sistemas durante a realização de uma tarefa prática simples. O teste será registrado em forma de fotos, vídeo e áudio e não deverá exigir mais do que 30 minutos para ser executado.
- Responder um questionário de avaliação da sua interação com a tecnologia que foi testada. O questionário não deve exigir mais do que 15 minutos para ser respondido.
- Participar de uma entrevista, que será registrada por fotos, vídeo, áudio e anotações em texto. A entrevista não deve exigir mais do que 30 minutos para ser realizada.

Rubrica do pesquisador:______________ Rubrica do participante:______________

Desconfortos e riscos:

Você **não** deve participar deste estudo se você for menor de idade ou se não estiver de acordo com os termos e procedimentos deste estudo.

Este estudo não possui riscos previsíveis, pois os testes serão feitos com equipamentos e dispositivos não invasivos. Eventuais desconfortos com o uso das tecnologias não serão propositais, já que esta pesquisa é centrada em acessibilidade e usabilidade, e preza, portanto, pelo conforto. Entretanto, desconfortos podem surgir durante a interação com a tecnologia e, nesses casos, serão um indicativo de que a tecnologia sendo testada precisa passar por modificações para tornar-se mais confortável.

Visando uma maior agilidade nos testes e maior conforto para os participantes, as atividades de leitura, preenchimento e assinatura do TCLE poderão ser realizadas no mesmo horário e local de realização dos testes. Será sempre respeitada a necessidade da leitura cautelosa, do entendimento e da assinatura do TCLE por parte dos candidatos antes que seja realizada qualquer outra atividade relacionada ao teste. Caso seja solicitado, o TCLE também poderá ser entregue anteriormente a qualquer voluntário, visando uma análise mais profunda das possíveis consequências oriundas da participação nos testes.

Benefícios:

É previsto que os voluntários aprendam a utilizar tecnologias digitais que não fazem parte do seu cotidiano.

Para os pesquisadores e para a comunidade científica em geral, as investigações conduzidas gerarão dados relevantes para pesquisas que envolvem direta ou indiretamente o uso de interfaces naturais (NUIs) no contexto de acessibilidade.

Acompanhamento e assistência:

Se qualquer participante sentir-se mal por consequência do esforço realizado, ele poderá descansar durante o tempo que for necessário, ou mesmo abandonar o teste, visando evitar riscos a sua saúde. Mesmo tendo assinado o termo (TCLE), a sua participação na pesquisa poderá ser interrompida a qualquer momento, sem que haja a necessidade de explicação do motivo ou qualquer forma de represália advinda desse fato.

Sigilo e privacidade:

Você tem a garantia de que sua identidade será mantida em sigilo e nenhuma informação será dada a outras pessoas que não façam parte da equipe de pesquisadores. Na divulgação dos resultados desse estudo, seu nome não será citado.

Ressarcimento:

Este estudo não prevê nenhum tipo de ressarcimento de despesas com transporte ou alimentação. O estudo será conduzido nos dias e horários que estiverem de acordo com a disponibilidade do participante.

Contato:

Em caso de dúvidas sobre o estudo, você poderá entrar em contato com a pesquisadora Vanessa Regina Margareth Lima Maike no Instituto de Computação da UNICAMP (Av. Albert Einstein 1251 - Cidade Universitária - Campinas/SP – Brasil CEP 13083-852), ou pelo e-mail vanessa.maike@gmail.com.

Em caso de denúncias ou reclamações sobre sua participação e sobre questões éticas do estudo, você pode entrar em contato com a secretaria do Comitê de Ética em Pesquisa (CEP) da UNICAMP: Rua: Tessália Vieira de Camargo, 126; CEP 13083-887 Campinas – SP; telefone (19) 3521-8936; fax (19) 3521-7187; e-mail: cep@fcm.unicamp.br

Rubrica do pesquisador:______________ Rubrica do participante:______________

Consentimento livre e esclarecido:

Após ter sido esclarecimento sobre a natureza da pesquisa, seus objetivos, métodos, benefícios previstos, potenciais riscos e o incômodo que esta possa acarretar, aceito participar:

Nome do(a) participante: ____

____ Data: ____/_____/______.
(Assinatura do participante ou nome e assinatura do seu responsável LEGAL)

Responsabilidade do Pesquisador:

Asseguro ter cumprido as exigências da resolução 466/2012 CNS/MS e complementares na elaboração do protocolo e na obtenção deste Termo de Consentimento Livre e Esclarecido. Asseguro, também, ter explicado e fornecido uma cópia deste documento ao participante. Informo que o estudo foi aprovado pelo CEP perante o qual o projeto foi apresentado. Comprometo-me a utilizar o material e os dados obtidos nesta pesquisa exclusivamente para as finalidades previstas neste documento ou conforme o consentimento dado pelo participante.

____ Data: ____/_____/______.
(Assinatura do pesquisador)

Rubrica do pesquisador:______________ Rubrica do participante:______________

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Investigando Natural User Interfaces (NUIs) – Tecnologias e Interação em Contexto de Acessibilidade
Vanessa Regina Margareth Lima Maike e Maria Cecília Calani Baranauskas
Número do CAAE: 31818014.0.0000.5404

Você está sendo convidado a participar como voluntário de um estudo. Este documento, chamado Termo de Consentimento Livre e Esclarecido, visa assegurar seus direitos como participante e é elaborado em duas vias, uma que deverá ficar com você e outra com o pesquisador.

Por favor, leia com atenção e calma, aproveitando para esclarecer suas dúvidas. Se houver perguntas antes ou mesmo depois de assiná-lo, você poderá esclarecê-las com o pesquisador. Se preferir, pode levar para casa e consultar seus familiares ou outras pessoas antes de decidir participar. Se você não quiser participar ou retirar sua autorização, a qualquer momento, não haverá nenhum tipo de penalização ou prejuízo.

Justificativa e objetivos:

Desde que os computadores foram criados, foi crescente não apenas a sua evolução, como também a sua presença na vida e no cotidiano das pessoas. Nos últimos anos, essa evolução levou a um novo paradigma de interação entre usuários e tecnologia, conhecido como Natural User Interfaces (NUIs), ou interfaces naturais. Esse novo paradigma promete reduzir ainda mais as barreiras entre a máquina e as pessoas e, ao mesmo tempo, dar mais poder ao usuário. Entretanto, é importante ressaltar que a força das interfaces naturais está presa a três elementos: aos contextos nos quais se encaixam, às maneiras como moldam a interação das pessoas com a tecnologia e aos tipos de tarefas que facilitam.

Pensando no cenário descrito, o objetivo principal deste projeto é propor melhores maneiras de construir tecnologias com interfaces naturais, no contexto de acessibilidade. Como objetivos secundários estão o design e a avaliação, dentro do contexto de acessibilidade, de novas tecnologias que também pertençam ao paradigma NUI.

Portanto, ao investigar diferentes tecnologias com NUIs em um contexto prático específico, com usuários reais e na realização de tarefas específicas, este projeto de pesquisa terá como consequência direta o fortalecimento das interfaces naturais não apenas como campo de pesquisa, mas como forma de interação em diferentes tecnologias.

O estudo de tecnologias com NUIs no contexto de acessibilidade também deve trazer benefícios para seus usuários, especialmente aqueles com deficiência. Além de possibilitar que esse grupo de usuários utilize uma gama maior de dispositivos, espera-se também uma melhoria nos tipos de usos que eles conseguirão fazer das tecnologias com NUIs à sua disposição.

Procedimentos:

Participando do estudo você está sendo convidado a:

- Realizar o teste de um ou mais sistemas computacionais que utilizem interfaces naturais. O teste consiste na utilização desses sistemas durante a realização de uma tarefa prática simples. O teste será registrado em forma de fotos, vídeo e áudio e não deverá exigir mais do que 30 minutos para ser executado.
- Responder um questionário de avaliação da sua interação com a tecnologia que foi testada. O questionário não deve exigir mais do que 15 minutos para ser respondido.
- Participar de uma entrevista, que será registrada por fotos, vídeo, áudio e anotações em texto. A entrevista não deve exigir mais do que 30 minutos para ser realizada.

Desconfortos e riscos:

Rubrica do pesquisador:______________ Rubrica do participante:______________

Você **não** deve participar deste estudo se você não estiver de acordo com os termos e procedimentos deste estudo.

Este estudo não possui riscos previsíveis, pois os testes serão feitos com equipamentos e dispositivos não invasivos. Eventuais desconfortos com o uso das tecnologias não serão propositais, já que esta pesquisa é centrada em acessibilidade e usabilidade, e preza, portanto, pelo conforto. Entretanto, desconfortos podem surgir durante a interação com a tecnologia e, nesses casos, serão um indicativo de que a tecnologia sendo testada precisa passar por modificações para tornar-se mais confortável.

Visando uma maior agilidade nos testes e maior conforto para os participantes, as atividades de leitura, preenchimento e assinatura do TCLE poderão ser realizadas no mesmo horário e local de realização dos testes. Será sempre respeitada a necessidade da leitura cautelosa, do entendimento e da assinatura do TCLE por parte dos candidatos antes que seja realizada qualquer outra atividade relacionada ao teste. Caso seja solicitado, o TCLE também poderá ser entregue anteriormente a qualquer voluntário, visando uma análise mais profunda das possíveis consequências oriundas da participação nos testes.

Benefícios:

É previsto que os voluntários aprendam a utilizar tecnologias digitais que não fazem parte do seu cotidiano.

Para os pesquisadores e para a comunidade científica em geral, as investigações conduzidas gerarão dados relevantes para pesquisas que envolvem direta ou indiretamente o uso de interfaces naturais (NUIs) no contexto de acessibilidade.

Acompanhamento e assistência:

Se qualquer participante sentir-se mal por consequência do esforço realizado, ele poderá descansar durante o tempo que for necessário, ou mesmo abandonar o teste, visando evitar riscos a sua saúde. Mesmo tendo assinado o termo (TCLE), a sua participação na pesquisa poderá ser interrompida a qualquer momento, sem que haja a necessidade de explicação do motivo ou qualquer forma de represália advinda desse fato.

Sigilo e privacidade:

Você tem a garantia de que sua identidade será mantida em sigilo e nenhuma informação será dada a outras pessoas que não façam parte da equipe de pesquisadores. Na divulgação dos resultados desse estudo, seu nome não será citado.

Ressarcimento:

Este estudo não prevê nenhum tipo de ressarcimento de despesas com transporte ou alimentação. O estudo será conduzido nos dias e horários que estiverem de acordo com a disponibilidade do participante.

Contato:

Em caso de dúvidas sobre o estudo, você poderá entrar em contato com a pesquisadora Vanessa Regina Margareth Lima Maike no Instituto de Computação da UNICAMP (Av. Albert Einstein 1251 - Cidade Universitária - Campinas/SP – Brasil CEP 13083-852), ou pelo e-mail vanessa.maike@gmail.com.

Em caso de denúncias ou reclamações sobre sua participação e sobre questões éticas do estudo, você pode entrar em contato com a secretaria do Comitê de Ética em Pesquisa (CEP) da UNICAMP: Rua: Tessália Vieira de Camargo, 126; CEP 13083-887 Campinas – SP; telefone (19) 3521-8936; fax (19) 3521-7187; e-mail: cep@fcm.unicamp.br

Consentimento livre e esclarecido:

Rubrica do pesquisador:_______________ Rubrica do participante:_______________

Após ter sido esclarecimento sobre a natureza da pesquisa, seus objetivos, métodos, benefícios previstos, potenciais riscos e o incômodo que esta possa acarretar, aceito participar:

Nome do(a) participante: ____

____ Data: ____/_____/______.
(Assinatura do participante ou nome e assinatura do seu responsável LEGAL)

Responsabilidade do Pesquisador:

Asseguro ter cumprido as exigências da resolução 466/2012 CNS/MS e complementares na elaboração do protocolo e na obtenção deste Termo de Consentimento Livre e Esclarecido. Asseguro, também, ter explicado e fornecido uma cópia deste documento ao participante. Informo que o estudo foi aprovado pelo CEP perante o qual o projeto foi apresentado. Comprometo-me a utilizar o material e os dados obtidos nesta pesquisa exclusivamente para as finalidades previstas neste documento ou conforme o consentimento dado pelo participante.

____ Data: ____/_____/______.
(Assinatura do pesquisador)

Rubrica do pesquisador:______________ Rubrica do participante:______________

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Investigando Natural User Interfaces (NUIs) – Tecnologias e Interação em Contexto de Acessibilidade

Vanessa Regina Margareth Lima Maike e Maria Cecília Calani Baranauskas

Número do CAAE: 31818014.0.0000.5404

Seu(sua) filho(a) está sendo convidado a participar como voluntário de um estudo. Este documento, chamado Termo de Consentimento Livre e Esclarecido, visa assegurar os direitos de seu(sua) filho(a) como participante e é elaborado em duas vias, uma que deverá ficar com você e outra com o pesquisador.

Por favor, leia com atenção e calma, aproveitando para esclarecer suas dúvidas. Se houver perguntas antes ou mesmo depois de assiná-lo, você poderá esclarecê-las com o pesquisador. Se preferir, pode levar para casa e consultar seus familiares ou outras pessoas antes de decidir se seu(sua) filho(a) deve participar. Se você não quiser que seu(sua) filho(a) participe ou se quiser retirar sua autorização, a qualquer momento, não haverá nenhum tipo de penalização ou prejuízo.

Justificativa e objetivos:

Desde que os computadores foram criados, foi crescente não apenas a sua evolução, como também a sua presença na vida e no cotidiano das pessoas. Nos últimos anos, essa evolução levou a um novo paradigma de interação entre usuários e tecnologia, conhecido como Natural User Interfaces (NUIs), ou interfaces naturais. Esse novo paradigma promete reduzir ainda mais as barreiras entre a máquina e as pessoas e, ao mesmo tempo, dar mais poder ao usuário. Entretanto, é importante ressaltar que a força das interfaces naturais está presa a três elementos: aos contextos nos quais se encaixam, às maneiras como moldam a interação das pessoas com a tecnologia e aos tipos de tarefas que facilitam.

Pensando no cenário descrito, o objetivo principal deste projeto é propor melhores maneiras de construir tecnologias com interfaces naturais, no contexto de acessibilidade. Como objetivos secundários estão o design e a avaliação, dentro do contexto de acessibilidade, de novas tecnologias que também pertençam ao paradigma NUI.

Portanto, ao investigar diferentes tecnologias com NUIs em um contexto prático específico, com usuários reais e na realização de tarefas específicas, este projeto de pesquisa terá como consequência direta o fortalecimento das interfaces naturais não apenas como campo de pesquisa, mas como forma de interação em diferentes tecnologias.

O estudo de tecnologias com NUIs no contexto de acessibilidade também deve trazer benefícios para seus usuários, especialmente aqueles com deficiência. Além de possibilitar que esse grupo de usuários utilize uma gama maior de dispositivos, espera-se também uma melhoria nos tipos de usos que eles conseguirão fazer das tecnologias com NUIs à sua disposição.

Procedimentos:

Participando do estudo seu(sua) filho(a) está sendo convidado a:

- Realizar o teste de um ou mais sistemas computacionais que utilizem interfaces naturais. O teste consiste na utilização desses sistemas durante a realização de uma tarefa prática simples. O teste será registrado em forma de fotos, vídeo e áudio e não deverá exigir mais do que 30 minutos para ser executado.
- Responder um questionário de avaliação da sua interação com a tecnologia que foi testada. O questionário não deve exigir mais do que 15 minutos para ser respondido.
- Participar de uma entrevista, que será registrada por fotos, vídeo, áudio e anotações em texto. A entrevista não deve exigir mais do que 30 minutos para ser realizada.

Rubrica do pesquisador:______________ Rubrica do participante:______________

Desconfortos e riscos:

Seu(sua) filho(a) **não** deve participar deste estudo se você e/ou ele não estiverem de acordo com os termos e procedimentos deste estudo.

Este estudo não possui riscos previsíveis, pois os testes serão feitos com equipamentos e dispositivos não invasivos. Eventuais desconfortos com o uso das tecnologias não serão propositais, já que esta pesquisa é centrada em acessibilidade e usabilidade, e preza, portanto, pelo conforto. Entretanto, desconfortos podem surgir durante a interação com a tecnologia e, nesses casos, serão um indicativo de que a tecnologia sendo testada precisa passar por modificações para tornar-se mais confortável.

Visando uma maior agilidade nos testes e maior conforto para os participantes, as atividades de leitura, preenchimento e assinatura do TCLE poderão ser realizadas no mesmo horário e local de realização dos testes. Será sempre respeitada a necessidade da leitura cautelosa, do entendimento e da assinatura do TCLE por parte dos candidatos antes que seja realizada qualquer outra atividade relacionada ao teste. Caso seja solicitado, o TCLE também poderá ser entregue anteriormente a qualquer voluntário, visando uma análise mais profunda das possíveis consequências oriundas da participação nos testes.

Benefícios:

É previsto que os voluntários aprendam a utilizar tecnologias digitais que não fazem parte do seu cotidiano.

Para os pesquisadores e para a comunidade científica em geral, as investigações conduzidas gerarão dados relevantes para pesquisas que envolvem direta ou indiretamente o uso de interfaces naturais (NUIs) no contexto de acessibilidade.

Acompanhamento e assistência:

Se qualquer participante sentir-se mal por consequência do esforço realizado, ele poderá descansar durante o tempo que for necessário, ou mesmo abandonar o teste, visando evitar riscos a sua saúde. Mesmo tendo assinado o termo (TCLE), a sua participação na pesquisa poderá ser interrompida a qualquer momento, sem que haja a necessidade de explicação do motivo ou qualquer forma de represália advinda desse fato.

Sigilo e privacidade:

Você tem a garantia de que a identidade de seu(sua) filho(a) será mantida em sigilo e nenhuma informação será dada a outras pessoas que não façam parte da equipe de pesquisadores. Na divulgação dos resultados desse estudo, o nome de seu(sua) filho(a) não será citado.

Ressarcimento:

Este estudo não prevê nenhum tipo de ressarcimento de despesas com transporte ou alimentação. O estudo será conduzido nos dias e horários que estiverem de acordo com a disponibilidade do participante.

Contato:

Em caso de dúvidas sobre o estudo, você poderá entrar em contato com a pesquisadora Vanessa Regina Margareth Lima Maike no Instituto de Computação da UNICAMP (Av. Albert Einstein 1251 - Cidade Universitária - Campinas/SP – Brasil CEP 13083-852), ou pelo e-mail vanessa.maike@gmail.com.

Em caso de denúncias ou reclamações sobre sua participação e sobre questões éticas do estudo, você pode entrar em contato com a secretaria do Comitê de Ética em Pesquisa (CEP) da UNICAMP: Rua: Tessália Vieira de Camargo, 126; CEP 13083-887 Campinas – SP; telefone (19) 3521-8936; fax (19) 3521-7187; e-mail: cep@fcm.unicamp.br

Rubrica do pesquisador:_______________ Rubrica do participante:______________

Consentimento livre e esclarecido:

Após ter sido esclarecimento sobre a natureza da pesquisa, seus objetivos, métodos, benefícios previstos, potenciais riscos e o incômodo que esta possa acarretar, aceito participar:

Nome do(a) participante: ____

____ Data: ____/_____/______.
(Assinatura do seu responsável LEGAL)

____ Data: ____/_____/______.
(Assinatura do(a) participante – caso tenha 14 anos ou mais)

Responsabilidade do Pesquisador:

Asseguro ter cumprido as exigências da resolução 466/2012 CNS/MS e complementares na elaboração do protocolo e na obtenção deste Termo de Consentimento Livre e Esclarecido. Asseguro, também, ter explicado e fornecido uma cópia deste documento ao participante. Informo que o estudo foi aprovado pelo CEP perante o qual o projeto foi apresentado. Comprometo-me a utilizar o material e os dados obtidos nesta pesquisa exclusivamente para as finalidades previstas neste documento ou conforme o consentimento dado pelo participante.

____ Data: ____/_____/______.
(Assinatura do pesquisador)

Rubrica do pesquisador:______________ Rubrica do participante:______________

Appendix E

Authorizations for Using Published Articles

Gmail

Vanessa Maike <vanessa.maike@gmail.com>

Thank you for your order with RightsLink / Springer Nature

no-reply@copyright.com <no-reply@copyright.com> Wed, Jul 11, 2018 at 2:23 PM
To: vanessa.maike@gmail.com

SPRINGER NATURE

Thank you for your order!

Dear Ms. Vanessa Maike,

Thank you for placing your order through Copyright Clearance Center's RightsLink® service.

Order Summary

Licensee:	Ms. Vanessa Maike
Order Date:	Jul 11, 2018
Order Number:	4386030444160
Publication:	Springer eBook
Title:	Heuristics for NUI Revisited and Put into Practice
Type of Use:	Thesis/Dissertation
Order Total:	0.00 USD

View or print complete details of your order and the publisher's terms and conditions.

Sincerely,

Copyright Clearance Center

Tel: +1-855-239-3415 / +1-978-646-2777
customercare@copyright.com
https://myaccount.copyright.com

Copyright Clearance Center RightsLink®

Gmail **Vanessa Maike <vanessa.maike@gmail.com>**

Thank you for your order with RightsLink / Springer Nature

no-reply@copyright.com <no-reply@copyright.com> Wed, Jul 11, 2018 at 2:24 PM
To: vanessa.maike@gmail.com

SPRINGER NATURE

Thank you for your order!

Dear Ms. Vanessa Maike,

Thank you for placing your order through Copyright Clearance Center's RightsLink® service.

Order Summary

Licensee:	Ms. Vanessa Maike
Order Date:	Jul 11, 2018
Order Number:	4386030552922
Publication:	Springer eBook
Title:	Designing Natural User Interfaces Scenarios for All and for Some: An Analysis Informed by Organizational Semiotics Artifacts
Type of Use:	Thesis/Dissertation
Order Total:	0.00 USD

View or print complete details of your order and the publisher's terms and conditions.

Sincerely,

Copyright Clearance Center

Tel: +1-855-239-3415 / +1-978-646-2777
customercare@copyright.com
https://myaccount.copyright.com

Copyright Clearance Center RightsLink®

ACM Information for Authors

Author Rights | FAQ

ACM Author Rights

ACM exists to support the needs of the computing community. For over sixty years ACM has developed publications and publication policies to maximize the visibility, impact, and reach of the research it publishes to a global community of researchers, educators, students, and practitioners. ACM has achieved its high impact, high quality, widely-read portfolio of publications with:

- Affordably priced publications
- Liberal Author rights policies
- Wide-spread, perpetual access to ACM publications via a leading-edge technology platform
- Sustainability of the good work of ACM that benefits the profession

CHOOSE

Authors have the option to choose the level of rights management they prefer. ACM offers three different options for authors to manage the publication rights to their work.

- Authors who want ACM to manage the rights and permissions associated with their work, which includes defending against improper use by third parties, can use ACM's traditional copyright transfer agreement.
- Authors who prefer to retain copyright of their work can sign an exclusive licensing agreement, which gives ACM the right but not the obligation to defend the work against improper use by third parties.
- Authors who wish to retain all rights to their work can choose ACM's author-pays option, which allows for perpetual open access through the ACM Digital Library. Authors choosing the author-pays option can give ACM non-exclusive permission to publish, sign ACM's exclusive licensing agreement or sign ACM's traditional copyright transfer agreement. Those choosing to grant ACM a non-exclusive permission to publish may also choose to display a Creative Commons License on their works.

POST

Authors can post the accepted, peer-reviewed version prepared by the author-known as the "pre-print"-to the following sites, with a DOI pointer to the Definitive Version of Record in the ACM Digital Library.

- On Author's own Home Page *and*
- On Author's Institutional Repository *and*
- In any repository legally mandated by the agency funding the research on which the work is based *and*
- On any non-commercial repository or aggregation that does not duplicate ACM tables of contents, i.e., whose patterns of links do not substantially duplicate an ACM-copyrighted volume or issue. Non-commercial repositories are here understood as repositories owned by non-profit organizations that do not charge a

fee for accessing deposited articles and that do not sell advertising or otherwise profit from serving articles.

DISTRIBUTE

Authors can post an *Author-Izer* link enabling free downloads of the Definitive Version of the work permanently maintained in the ACM Digital Library

- On the Author's own Home Page *or*
- In the Author's Institutional Repository.

REUSE

Authors can reuse any portion of their own work in a new work of *their own* (and no fee is expected) as long as a citation and DOI pointer to the Version of Record in the ACM Digital Library are included.

- Contributing complete papers to any edited collection of reprints for which the author is *not* the editor, requires permission and usually a republication fee.

Authors can include partial or complete papers of their own (and no fee is expected) in a dissertation as long as citations and DOI pointers to the Versions of Record in the ACM Digital Library are included. Authors can use any portion of their own work in presentations and in the classroom (and no fee is expected).

- Commercially produced course-packs that are *sold* to students require permission and possibly a fee.

CREATE

ACM's copyright and publishing license include the right to make Derivative Works or new versions. For example, translations are "Derivative Works." By copyright or license, ACM may have its publications translated. However, ACM Authors continue to hold perpetual rights to revise their own works without seeking permission from ACM.

- If the revision is minor, i.e., less than 25% of new substantive material, then the work should still have ACM's publishing notice, DOI pointer to the Definitive Version, and be labeled a "Minor Revision of"
- If the revision is major, i.e., 25% or more of new substantive material, then ACM considers this a new work in which the author retains full copyright ownership (despite ACM's copyright or license in the original published article) and the author need only cite the work from which this new one is derived.

Minor Revisions and Updates to works already published in the ACM Digital Library are welcomed with the approval of the appropriate Editor-in-Chief or Program Chair.

RETAIN

Authors retain all *perpetual rights* laid out in the ACM Author Rights and Publishing Policy, including, but not limited to:

- Sole ownership and control of third-party permissions to use for artistic images intended for exploitation in other contexts
- All patent and moral rights
- Ownership and control of third-party permissions to use of software published by ACM

Have more questions? Check out the FAQ.

back to top

Figure E.1: ACM Author Rights: `https://authors.acm.org/main.html`