Journal of the Brazilian Computer Society, 2026, 32:1, doi: 10.5753/jbcs.2026.5821

"Mamma mia! Autocorrection ruined my message": Interaction design challenges in a world of multilinguals

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Received: 01 April 2025 • **Accepted:** 27 September 2025 • **Published:** 22 April 2026

Abstract The widespread adoption of digital technologies and internet connectivity, particularly in developing regions, has drawn attention to the growing diversity of software users, who come from different cultural and linguistic backgrounds. Traditionally, human-computer interaction (HCI) research has treated language communities as static and isolated units, often equating them with national boundaries. However, linguistic research demonstrates that cultures are dynamic and interconnected, languages transcend borders, and people frequently speak two or more languages. To optimize HCI design, developers must account for these complex sociolinguistic realities, incorporating both social and individual dimensions of multilingualism. In this work, our aim is to contrast the demands of multilingual users with current design solutions. First, the behavior and difficulties of technology users in multilingual contexts were investigated through an online survey conducted with the academic communities of two universities: the Università della Svizzera italiana (USI), in Switzerland, and the Pontifical Catholic University of Rio Grande do Sul (PUCRS), in Brazil. Next, we present a pattern language that describes solutions aimed at multilingualism issues found in current websites and applications. In a final discussion, we compare the findings of the survey with the patterns, summarizing the challenges and opportunities for future research that aim to propose HCI design approaches with a focus on multilingualism.

Keywords: Human-Computer Interaction, HCI Design, Multilingualism, Design Patterns, Pattern Language

1 Introduction

Following the turn of the millennium, highly diverse social landscapes began to be observed in certain countries due to increased mobility, a phenomenon that Vertovec called *super-diversity* [Vertovec, 2007]. Meanwhile, the world saw a popularization of computing devices and Internet connectivity, especially in developing countries [Campbell-Kelly *et al*., 2023]. These changes, along with the advent of the participatory web[1] [Blank and Reisdorf, 2012], draw attention to an increasing number of software users with varying cultural and linguistic backgrounds [Abufardeh and Magel, 2010; Gasparini *et al*., 2011; Salgado *et al*., 2015].

Regarding the user language aspect, a common mistake in interaction design is to consider language communities as static and isolated entities, frequently associating them with a specific nation or administrative region. Associating the icon of a country flag with a language is a bad practice that can be associated with this misconception[2]. A similar oversight also occurs at the individual level, when designers consider that users are either monolinguals or multilinguals who use each language separately at different moments [Hale, 2014a].

However, most sociologists and linguists agree that cultures constantly interact and exchange ideas, languages spread within and across country borders, and individuals often speak two or more languages. The perspective of *polyculturalism* [Kelley, 1999; Rosenthal and Levy, 2010], for example, emphasizes the connections between cultures (rather than their differences) and acknowledges them as dynamic, interactive, and impure entities (rather than static and isolated) [Haslam, 2017]. Similarly, code-meshing [Canagarajah, 2006], polylingualism [Jørgensen, 2008], translanguaging [García, 2009], and plurilingualism [Piccardo, 2013] are notions proposed by linguists that criticize the underlying conception of languages as separate entities and focus on capturing the dynamic aspect of language use or the holistic and hybrid nature of linguistic phenomena and practices [Piccardo, 2018].

For an effective design of human-computer interaction (HCI), developers should consider the dynamic aspect of societal and individual multilingualism. In this study, to map the challenges and opportunities in the intersection between multilingualism and interaction design, we contrast the demands of multilingual users with current design solutions. First, user behavior and challenges in multilingual technology contexts were investigated via an online survey administered to students in Switzerland and Brazil. Subsequently, we outline

[1] Participatory web, also known as Web 2.0, refers to websites that emphasize user-generated content, participatory culture and interoperability [O'reilly, 2009; Blank and Reisdorf, 2012].

[2] Using flags to represent languages is considered a bad practice by the World Wide Web Consortium (W3C) at least since 2005 [Ishida, 2005]. The same point of view is shared by many designers and user experience professionals [Johansson, 2006; Jovanovic, 2008; Korpela, 2016; Yunker, 2018b; Sergushkin.com, 2023; Offer, 2024].

design patterns that capture existing solutions implemented in contemporary websites and applications. Finally, we discuss the alignment between the survey findings and the identified patterns, synthesizing key challenges and potential avenues for future research aimed at advancing HCI design methodologies with a focus on multilingualism.

An online survey was conducted with the academic communities of two universities: Università della Svizzera italiana (USI) in Switzerland, and Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS) in Brazil. Switzerland has a long tradition of multilingualism, whereas Brazil is generally considered a monolingual country (see Section 3 for more details). Choosing two countries with distinct linguistic contexts allowed comparison and a more in-depth analysis of the results. Participants have been asked about their level of multilingualism, activities performed online in multiple languages, and problems faced during this interaction. The results confirm a high level of multilingualism in general, but higher among participants in Switzerland. The types of tasks and the language-related issues reported by the participants varied between the two settings, indicating that the level of multilingualism impacts users' behavior and difficulties faced when interacting with digital devices.

This work is an extended and revised version of a paper originally published in the proceedings of XXIII Brazilian Symposium on Human Factors in Computing Systems (IHC 2024) [Da Rosa *et al*., 2024]. As new contribution, a pattern language comprised of 40 patterns is presented, while four patterns are highlighted and described in detail. These patterns are part of ongoing research on the design implications of multilingualism in current software user interfaces (UI) (other results from this research project can be found in Da Rosa and Silveira [2022]; Da Rosa *et al*. [2022, 2023b]; Da Rosa [2024]). The main criteria for selecting the four patterns were their maturity level and connection to the survey results. In a final discussion (updated from the original version), we compare the survey findings with the design patterns, summarizing the challenges and opportunities for future research that aim to propose HCI design approaches with a focus on multilingualism. For an introduction to design patterns in the context of HCI, see Section 2.2. The methodology used in the development of the patterns is explained in Section 4.2. In Section 6, the description of the patterns is presented.

This paper consists of eight sections, including this introduction. Section 2 presents the theoretical background and other HCI studies related to the intersection of multilingualism and HCI. A brief characterization of the linguistic landscapes of Switzerland and Brazil is presented in Section 3. Sections 4, 5 and 6 present the methodology, survey results, and design patterns, respectively. Analysis of the results and possible implications for HCI are discussed in Section 7. Finally, Section 8 presents the limitations of the study, final considerations, and future work.

2 Theoretical basis and related work

This section compiles theoretical background and other works related to language aspects of human-computer interaction, design patterns, and multilingualism. Section 2.1 situates language concerns in the context of more recent waves of HCI. Design patterns and their application in HCI are introduced in Section 2.2. The intersections between multilingualism and interaction design, including more recent studies on these topics, is the subject of Section 2.3.

2.1 Waves of HCI and the language aspect

The transformation caused by high connectivity, smartphones, and Web 2.0 increased the user base of many software systems and the cultural diversity among these users. More international, multicultural, and multilingual users raised new concerns among the HCI community, motivating research in areas such as cross-cultural design [Bourges-Waldegg and Scrivener, 1998], culturability [Barber and Badre, 1998], HCI for development (HCI4D) [Ho *et al*., 2009], sustainable HCI (SHCI) [DiSalvo *et al*., 2010], activity-centered design (ACD) [Norman, 2013], and accessibility [Persson *et al*., 2015]. By the mid-2000s, researchers coined the term Third Wave HCI to describe the shift in focus to broadened contexts, computer ubiquity, and culture awareness [Bødker, 2006]. Ten years later, an emerging fourth wave was envisioned, placing "politics and values and ethics" at the forefront without abandoning the strengths of previous waves [Ashby *et al*., 2019; Blevis *et al*., 2014; Bødker, 2015].

Aligned with the third and fourth waves, the definition of human-centered design in the ISO_9241-210:2019 [2019][3] standard explicit mentions human well-being, accessibility, and sustainability, highlighting the concern with ethical and social aspects. Despite intersections of multilingualism with the topics of accessibility and sustainability, this issue has only marginally been addressed in HCI research.

2.2 HCI design patterns

An approach that is frequently adopted to identify and document design strategies in HCI is that of *patterns* and *pattern languages*. Initially proposed by Alexander in the area of architecture [Alexander, 1977], the two concepts were subsequently adopted in other disciplines, including software engineering [Gamma, 1995] and human-computer interaction [Borchers, 2000]. According to Alexander, each pattern describes a problem that occurs recurrently in an environment and then describes the core of the solution to that problem [Alexander, 1977]. When related patterns are woven together, they form a language that provides a process for the orderly resolution of problems [Schmidt *et al*., 1996].

A pattern is documented through a combination of textual and visual elements that describe the problem that the pattern solves and the observed solution. Since the inception of patterns, there have been many attempts to determine the best attributes of a pattern. Some examples of these attempts, include: Alexander's original proposal of a pattern structure in the area of architecture[4] [Alexander, 1977]; the Gang of Four[5] [Gamma, 1995] and the Pattern Languages of Programs

[3] ISO stands for International Organization for Standardization, and ISO 9241-210:2019(en) is the current standard for human-centered design.

[4] Also known as the Alexandrian Format.

[5] Gang of Four, or GoF, are terms used to refer to the four authors of seminal book *Design Patterns: Elements of Reusable Object-Oriented*

(PLoP) community[6] adaptations for the area of software engineering; and Borchers proposed structure for patterns in interaction design [Borchers, 2000].

Regarding the application of patterns in real software projects, Schmidt states that patterns not only teach useful techniques but can help people communicate better, reason about what they do and why, and learn new design paradigms or architectural styles [Schmidt *et al*., 1996]. Dearden and Finlay, in turn, reviewing the first years of HCI research on patterns, identified five different ways in which patterns were useful in the context of HCI: enabling users to actively engage in a participatory design process; helping to support design debates as a specialist technical lexicon; serving as a tool for the management of organizational memory and knowledge; assisting as a lingua franca in multidisciplinary projects; and providing design rationale for particular design decisions [Dearden and Finlay, 2006]. Over the past 28 years, patterns have been the subject of research by HCI researchers [Da Rosa and Silveira, 2022; Gray *et al*., 2018; Schulte *et al*., 2016; Pan and Stolterman, 2013; Kruschitz and Hitz, 2010], but the extent of their adoption as a practical design tool has been a matter of debate [Seffah, 2015; Pan and Stolterman, 2013; Dearden and Finlay, 2006]. Despite this apparent low usage rate of HCI patterns, the subject still attracts the attention of the academic community [Mildner *et al*., 2023; Karlsson *et al*., 2022], and a framework for HCI patterns development was recently proposed [Da Rosa and Silveira, 2022].

2.3 Multilingualism intersections with HCI

In general, the term multilingualism is defined from two perspectives: it can be the coexistence of different language communities within a society, or it can refer to the use of more than one language by an individual speaker [Cenoz, 2013]. Historically, software engineers have dealt with the social dimension (the multilingualism of a target population) with strategies such as internationalization (i18n) and localization (L10n) [Esselink, 2003]. Despite evidence that there are more multilingual individuals in the world than monolingual [Tucker, 1998; Wei, 2000], the individual dimension (the multilingualism of each user) has been ignored for a long time and has only recently attracted the attention of user interface designers and HCI researchers. In 2014, Hale used for the first time the term "design for multilinguals" in a blog post stating that designers should "allow each user to have a set of multiple preferred languages; or, more simply, consider bilingual and multilingual users when designing platforms" [Hale, 2014a].

Over the last decade, the intersections between multilingualism and HCI have been a research topic for Hale and a few other HCI scholars. Most of these publications are focused on the study of content generated by multilingual users in social systems such as Wikipedia[7] [Hale, 2014c; Hecht and Gergle, 2010], Twitter[8] [Eleta and Golbeck, 2012; Kim *et al*., 2014], and TripAdvisor[9] [Hale, 2016]. By conducting a prototype study, Hale further explored user behavior regarding multilingual user reviews [Hale and Eleta, 2017]. In two other studies, the same author analyzes the links between user-generated content from blogs and microblogs in different languages [Hale, 2012, 2014b]. The behavior of multilingual users has also been studied in the context of developing countries [Wei and Kolko, 2005; Karusala *et al*., 2018] and underrepresented populations [Papalexakis and Doğruöz, 2015].

The aforementioned studies focus on the behavior and generated content of multilingual users interacting with digital systems without delving into the design implications of the findings. Not many papers on design strategies for multilingualism and language diversity were found. Normand et al. discuss how public policies in multilingual countries influence the use of language in the design of interactive systems [Normand *et al*., 2014]. Some studies in the information retrieval community focus on the design of multilingual search interfaces [Chu and Komlodi, 2017; Ling *et al*., 2018; Steichen and Freund, 2015; Steichen *et al*., 2024]. This type of interface allows users to retrieve multilingual information, that is, to submit multiple translated versions of a search term and visualize the resulting list of multilingual content (usually summarized information from websites). Da Rosa et al. analyzed existing applications and websites [Da Rosa *et al*., 2021; Da Rosa and Pons, 2017] and adopted a patterns approach to describe design solutions aimed at design for multilingualism [Da Rosa *et al*., 2022]. The pattern language developed by this author was further increased with patterns of reading assistance [Da Rosa *et al*., 2023b] and yielded theoretical considerations regarding the human language aspect in HCI [Da Rosa *et al*., 2023a].

More recent studies assess user experience in different multilingual contexts. The challenges and expectations of multilingual code-mixing users are explored by Choi *et al*. [2023] in the context of conversational agents. Kim *et al*. [2024] investigate how immigrants with limited English proficiency interact with a multilingual mHealth application. The user experience in the context of multilingual personal information management is the focus of Alon and Krtalić [2024]. Finally, Weir *et al*. [2025] proposes an examination of linguistic and cultural diversity in human-computer interaction from an accessibility perspective.

The research presented in this paper emphasizes the importance of considering both the multilingualism of the user base and the multilingualism of individual users in the context of interaction design. The term *design for multilingualism* is henceforth used in this work to denote this approach. No study was found in the literature adopting a survey (or any related research method) to analyze the implications of societal and individual multilingualism in technology users' behavior and difficulties.

Software, namely: Erich Gamma, Richard Helm, Ralph Johnson, and John Vlissides.

[6] Pattern Languages of Programs, or PLoP, is a group of annual conferences focused on software design patterns, held since 1994, and sponsored by The Hillside Group.

[7] `https://www.wikipedia.org`

[8] `https://twitter.com`

[9] `https://www.tripadvisor.com`

3 The multilingualisms of Switzerland and Brazil

The countries where this research took place, Switzerland and Brazil, are two examples of multilingual countries with different characteristics. Regardless of its smaller size, Switzerland recognizes four national languages and maintains a tradition of support for multilingualism. Despite having a greater number of languages used within its territory, Brazil has a history of institutional monolingualism, promoting Portuguese as the only official language at national level. Fig. 1 shows language characteristics of each country.

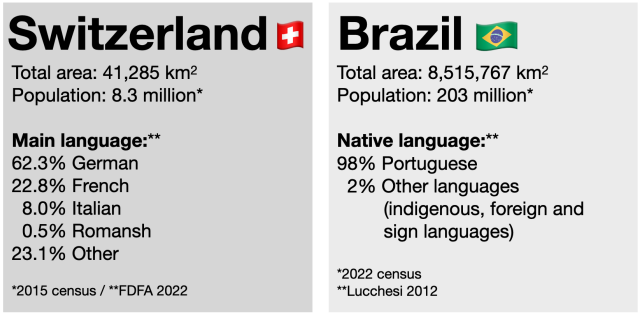

Figure 1. Basic information about the two countries and language statistics.

3.1 Multilingualism in Switzerland

Despite being smaller than Brazil in area and population, Switzerland has a rich linguistic culture. The Swiss economy is considered advanced, and the country has the highest Human Development Index (HDI) in the world (0.962) [United Nations Development Programme (UNDP), 2022]. Since the foundation of modern Switzerland in 1848, the country has been declared a multilingual state recognizing German, French, Italian, and later Romansh as national languages.

The rugged terrain dominated by the Alps, the proximity to countries with different linguistic settings, and the constant influx of immigrants favor the existence of several languages and dialects in Switzerland. Swiss German, for example, is an umbrella term for the many Alemannic German dialects spoken in Switzerland. Standard Swiss German is the standard language used mostly for writing in the German-speaking part of the country. Similarly, Romansh comprises many dialects grouped into five varieties, each with its own written form. *Rumantsch Grischun* is the standardized variety intended for written communication in Romansh-speaking regions. Besides the four official languages and their dialects, there are also speakers of Lombard, Franco-Provençal, and several immigrant languages.

At school, all children in Switzerland learn at least one of the other national languages and English [Demont-Heinrich, 2005]. English is sometimes used as a lingua franca between citizens from different regions and as an education language in some universities. Individual multilingualism is thus frequent, and over two-thirds of the Swiss people over the age of 15 regularly use more than one language [Federal Department of Foreign Affairs (FDFA), 2024].

The distribution of languages in Switzerland is not balanced, though. According to the Swiss government, 62.3% of the population speaks German or Swiss German as the main language, 22.8% French, 8.0% Italian, 0.5% Romansh, and 23.1% other languages[10] [Federal Department of Foreign Affairs (FDFA), 2024]. Despite the apparent harmony of Swiss multilingualism, some language-related tensions have been observed, such as the smaller minorities being neglected by the German-speaking majority and by the larger French-speaking minority; isolation of Swiss German due to the extensive use of spoken dialects; ethnification and the formation of language divides; and disagreements between cantons on the weighting of national languages versus English in educational language policy [Stępkowska, 2019; Stotz, 2006].

As a result of the dominance of Swiss German in the canton of Grisons, Romansh-speaking communities are now restricted to receding areas. The Romansh language is classified as *endangered* by the United Nations Educational, Scientific and Cultural Organization (UNESCO)[11]. Furthermore, a language that is dominant at one level may also be a minority language at another one: for instance, Italian is, at the same time, dominant in the canton of Tessin (in regard to the Lombard dialects) and a minority language at the national level (compared to French and Swiss German).

3.2 Multilingualism in Brazil

Brazil is considered a developing country, with a high HDI of 0.754 [United Nations Development Programme (UNDP), 2022], historical economic inequalities [Azzoni, 2001; Firpo and Portella, 2019], and much larger area and population compared to Switzerland (206 times larger in area and 24 times larger in population). Portuguese is spoken by the vast majority of the Brazilian population [Lucchesi, 2012] and is the sole official language at the national level, even though many minority languages (indigenous or immigrant) have co-official status in different municipalities.

Despite being regarded as a monolingual country by part of the general public, around 200 minority languages are also used in Brazil, ranking it among the ten countries with the highest number of languages in the world [Eberhard *et al.*, 2023]. The exact amount of minority languages currently spoken in Brazil is uncertain though, as this information is not collected in the country's census and, in the 2010 and 2021 censuses, only citizens who self-declared as belonging to indigenous ethnicities responded to the language questionnaire. Minority languages in Brazil include around 180 indigenous languages, languages spoken by immigrants and their descendants (mostly European), and two sign languages. The estimated number of living indigenous languages in Brazil varies from 150 [Storto, 2019] to 274 [Insituto Brasileiro de Geografia e Estatística (IBGE), 2010] (the difference is due to some languages declared in the census being variations or dialects of other languages). Among the languages used by immigrants, the Talian (a dialect of the Venetian language) [Comiotto, 2021] and the Hunsrik (*Riograndenser*

[10] In the Swiss census, citizens can inform more than one main language. Non-national languages, such as English, Portuguese, Albanian, Spanish, Serbian, and Croatian are mostly spoken by immigrant communities.

[11] See the page of Romansh on the UNESCO website: `https://en.wal.unesco.org/languages/romansh`.

Hunsrückisch, a German dialect) [Altenhofen and Morello, 2018] stand out, both with an estimated number of speakers above 500,000 and co-official status in many towns.

Individual multilingualism is common among speakers of minority languages, most of whom also speak Portuguese. Other causes for individual multilingualism include the proximity to the border with other South American countries (mainly Spanish-speaking) and the mandatory teaching of foreign languages (mainly English) in schools.

Nonetheless, the level of multilingualism in Brazil has been much higher in the past. An estimated number of indigenous languages existing in Brazil before the arrival of the first European settlers is 1,175 [Rodrigues, 1993], which results in an approximate number of 1,000 languages becoming extinct along the 322 years of Portuguese rule and 200 years of independent Brazilian state. This drastic reduction in Brazil's linguistic diversity, which is still ongoing today, is mainly due to two factors: the extermination of Brazilian indigenous peoples caused by Portuguese colonial practices (maintained during the imperial period and little attenuated during the Brazilian Republic) [Rodrigues, 1993]; and repressive language policies and language eradication strategies imposed by rulers of Portugal and Brazil that contributed to the reinforcement of Portuguese as a Brazilian national language [Cavalcanti and Maher, 2017]. Despite having a rich and varied culture, much of Brazil's linguistic diversity is at risk of disappearing in the coming decades.

Switzerland and Brazil are examples of different multilingual contexts, each with its challenges and opportunities. Socially conscious and sustainable design practices that equally value and respect all languages can play an important role in conserving cultural-linguistic diversity in these countries.

3.3 Locations of this study

This research covered members of the academic communities from Università della Svizzera italiana (USI, literally University of Italian Switzerland) in Switzerland and from Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS, literally Pontifical Catholic University of Rio Grande do Sul) in Brazil. The institutions were chosen for convenience as the authors had connections in both universities, which facilitated the conduction of the study. Furthermore, Switzerland and Brazil are very distinct countries, which allowed for the investigation of users' behavior in diverse cultural and linguistic contexts. Although the emphasis was on university students, other members of the academic communities, such as researchers and professors, were also accepted as valid respondents.

USI is located in the canton of Ticino, Southern Switzerland. The estimated total number of students in 2023 was 4,000 according to the university's website (`https://www.usi.ch/en`). Italian is the canton's official language, and courses are taught in either Italian or English.

In turn, PUCRS is located in the state of Rio Grande do Sul, Southern Brazil. The total number of students in 2024 (in-person and remote) is estimated to be 40,000 according to the official website (`https://www.pucrs.br/en/`). Most courses are taught in Portuguese, with a few exceptions.

4 Methodology

This paper reports the results of two complementary studies. Fig. 2 shows an overview of the methodology adopted in the work. The first study consisted of an online survey with students from two universities, one in Switzerland and the other in Brazil. The second study was part of a larger research project and consisted of developing design patterns focused on multilingualism. The results of the two studies were subsequently discussed and compared, revealing challenges and opportunities for research on the intersection of interaction design and multilingualism.

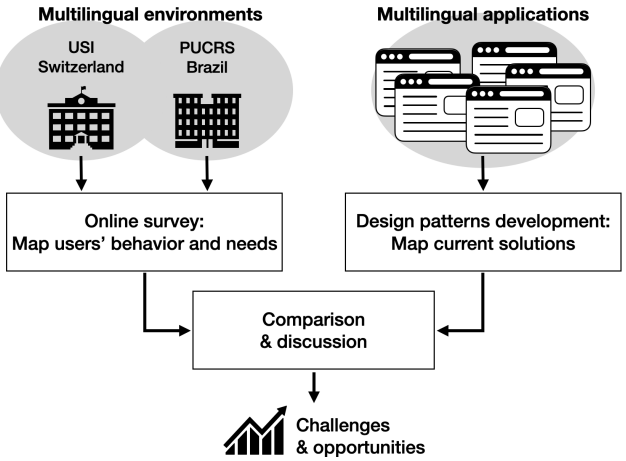

Figure 2. Overview of the adopted methodology: online survey, design patterns development, and final discussion.

Section 4.1 details the methodology adopted for the online survey, and Section 4.2 describes the development process of the design patterns. The survey results, the selected design patterns, and the final discussion comparing both can be found in Sections 5, 6, and 7 respectively.

4.1 Online survey methodology

The first study was planned and conducted following typical guidelines for surveys in Human-Computer Interaction research [Lazar *et al*., 2017] (see Fig. 3). The questionnaire was built on the Qualtrics platform, and the answers were stored on a secure server of one of the universities. All the contents of the questionnaire were translated and localized in English, Italian, and Portuguese languages. The informed consent forms and the questionnaires were submitted to the research ethics committees of both universities (see Section 8.3 for more details). After approval by the committees, a pilot study was conducted with six colleagues: four Italians, one Brazilian, and one Croatian, all fluent in English. No substantial changes were deemed necessary; however, cosmetic adjustments to the questionnaire were made in response to the feedback received. An example of these changes occurred in the questions asking about the canton and state of birth of participants born in Switzerland and Brazil respectively: in the Qualtrics system, the open questions were replaced by list selection, speeding up completion. These modifications, more related to the presentation of the questionnaire, did not require resubmission to the ethics committees. Finally, the questionnaire was made public in the platform and the

distribution/answering phase began.

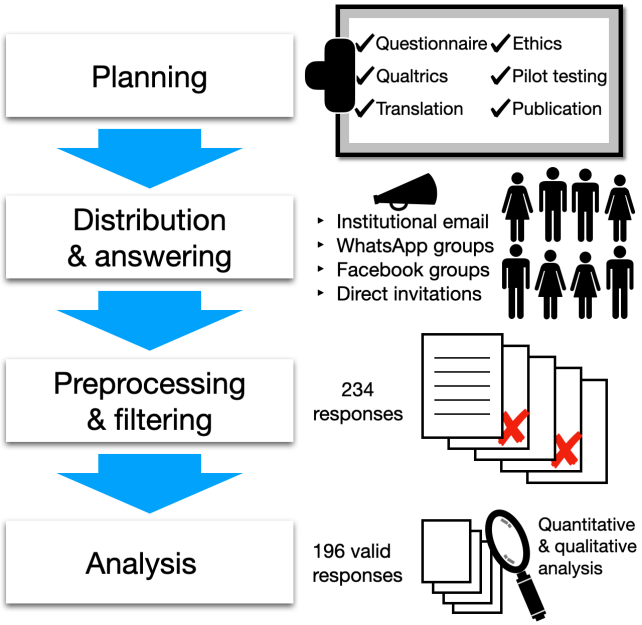

Figure 3. Survey methodology: planning, conduction, and analysis.

The survey was mostly self-selected and used convenience nonprobability sampling. Participants were recruited through instant messaging groups (WhatsApp), social network groups (Facebook), institutional email, and direct in-person invitations. To detect sampling bias, a reasonable amount of demographic data was collected (limitations of the survey are discussed in subsection 8.2). The responses were collected between August and November of the same year and 234 participants answered the survey: 116 in Switzerland and 118 in Brazil.

Both questionnaires were identical except for the question that asked the participant's administrative region of birth (subnational entity): in the Swiss version, Swiss citizens were asked their *canton* of birth; in the Brazilian version, Brazilian citizens were asked their *state* of birth; and in both versions, citizens from other countries informed only their country of birth. The Swiss questionnaire included translated versions in Italian (the region's official language) and English. In contrast, the Brazilian version was available in Portuguese (the official language of Brazil), Italian, and English. Only participants who reached the end of the online questionnaire had their responses validated and later analyzed. Twenty-two responses from Switzerland and 16 from Brazil were discarded due to participants rejecting the consent form, leaving questions blank, or not reaching the end of the form.

The remaining questionnaire responses, those considered valid, were analyzed with the aid of an electronic spreadsheet for tabulation and manipulation of the results. Responses to open-ended questions were analyzed using thematic analysis [Braun and Clarke, 2012]. Because the volume of text was not big, no other software tool was used for this purpose.

4.2 Design patterns development process

The process of developing the patterns followed the HCI patterns development framework described in Da Rosa and Silveira [2022]. The planning phase included choosing the appropriate pattern structure (see Table 1) and searching for similar preexisting patterns. The main steps of the discovery phase were the identification, confidence rating, organization, and validation of the patterns. The levels of confidence were expressed using the one-to-three-star scale proposed by Guerra and Fernandes [2010], in which one star identifies an incipient pattern and three stars identifies a well established pattern.

Table 1. The main attributes used to describe each pattern.

Attribute	Description
Name	A direct easy-to-remember name that identifies the pattern unambiguously.
Summary	A summary of the pattern solution.
Illustration	An image of the pattern in a real system.
Context	The conditions under which a problem can be solved by a pattern.
Problem	The problem being solved by the pattern.
Solution	Generic approach to solving the problem.
Diagram	An image, often including annotations, that describes how the solution works.
Confidence	The perceived level of confidence, significance, and/or maturity of the solution.
Known uses	Real-world examples of pattern usage.

The patterns were identified after reviewing 105 computing systems, including operating systems, desktop applications, mobile applications, and websites. The final list of systems was built on the basis of multiple criteria and can be found in Appendix 1 at the end of this paper. Popular software and hardware were added based on online rankings, and the list was complemented by exploratory research. These were the criteria adopted for the final list:

- **Similarweb**[12] ranking of the most visited websites in October 2023. The five most visited websites of ten segments were selected. The segments included were chosen based on previous studies showing that they comprised the websites with the most adaptations for multilingualism [Da Rosa, 2017; Da Rosa *et al.*, 2021, 2022]: *Accommodation and Hotels*, *Air Travel*, *Books and Literature*, *Cooking and Recipes*, *Dictionaries and Encyclopedias*, *Marketplace*, *Search Engines*, *Social Networks and Online Communities*, *Tourist Attractions*, and *TV Movies and Streaming*. A total of 50 websites were included by this criteria. The list of the most used web browsers from SimilarWeb October 2023 was also combined with that of StatCounter to determine the choices of that category.
- **StatCounter**[13] (October 2023) and **Statista**[14] (July 2023) rankings of the most popular web browsers and

[12] Similarweb Ltd. (`www.similarweb.com`) is an American company specializing in web analytics, traffic, and performance.

[13] StatCounter (`statcounter.com`) is an Irish company specializing in web traffic analysis.

[14] Statista (`www.statista.com`) is a German online platform focused on data gathering and visualization.

operating systems. Four web browsers, three desktop operating systems, and two mobile operating systems were included based on these rankings.
- **Web Globalization Report 2023**[15] listed the 25 top international websites that presented the best globalization characteristics. Nineteen websites from that list that had not yet been added to the selection were included.
- **Exploratory research** of additional software and hardware to include relevant systems that did not fit any of the previous categories. This list included desktop software, virtual keyboards, mechanical keyboards, mobile applications, and websites. A total of 27 systems were included by exploratory research.

During the organization step, the patterns were classified into categories according to their main functionality and relations between the patterns have been elicited. The classification and the names of the categories were inspired by the organization of two well-known user interface pattern libraries: Welie.com[16] and UI-Patterns.com[17]. The process resulted in a pattern language comprised of 40 patterns, which was then validated through two user studies: a focus group with experienced professionals and a design workshop with beginners. In both studies, the participants were members of the PUCRS academic community. The patterns were positively evaluated on quality criteria such as findability, feasibility, and effectiveness.

The connection between the survey results and the developed pattern language is two-fold, meaning that both influenced each other. At the time of the survey, preliminary studies had already been conducted and a first version of the patterns had been published [Da Rosa *et al*., 2022]. The early findings from the inspected systems helped us construct the survey questionnaire. Subsequently, during the development of the final version of the language, analysis of the survey results impacted different aspects of the process: the list of selected systems has been revised and expanded; patterns were added and others removed; and the description and organization of the patterns was rethought, arriving at its current format.

5 Survey results: mapping users' behaviors and needs

In total, 196 valid responses were analyzed (94 in Switzerland and 102 in Brazil) producing the results presented in this section. The subsections reflect the main topics covered by the questionnaire: demographic data, language abilities, activities involving multiple languages, and problems faced by the participants.

5.1 Demographic data

Regarding the demography of participants, at USI, 64.9% identified themselves as male, 31.9% identified as female, and 1.1% identified as non-binary. At PUCRS, 47.0% of the participants identified themselves as male, 52.0% identified as female, and 1.0% identified as non-binary. Most participants from USI (56.4%) belonged to the age group of 25-34 years. At PUCRS, most participants belonged to the age group of 18-24 years (67.6%).

At USI, most of the participants were graduate students (41.5% in master's and 35.1% in PhD courses); while, at PUCRS, the majority were undergraduate students (78.4%). Only nine participants were not students (professors, visitors, etc.): four at USI and five at PUCRS. In both sites, most participants were from Computing, Artificial Intelligence, or similar programs (70.2% at USI and 42.2% at PUCRS). Regarding the place of birth, USI presented a higher level of diversity. Participants at the Swiss university mentioned a total of 32 countries: Italy (35.1%) and Switzerland (8.5%) were the most cited. At PUCRS, 99.0% of respondents were born in Brazil. The Brazilian university had a single foreign participant (a student from Japan). For more details regarding the demography of the survey, see Fig. 4.

5.2 Linguistic diversity and multilingualism

Samples from USI also presented a higher level of linguistic diversity, as evidenced by Fig. 5. USI's participants have mentioned a total of 47 different languages, 44.7% of them reporting Italian as a native language (L1). In Brazil, participants reported some level of proficiency in 12 different languages, and 99.0% of participants were Portuguese native speakers. Some participants mentioned learning other languages in early childhood concurrently with Portuguese, such as English (16.7%) and Spanish (5.9%), but only one respondent reported Japanese as his/her only mother tongue. The level of multilingualism was higher among participants from USI: on average, respondents self-declared some level of knowledge in 4.14 languages (SD = 1.48). At PUCRS, the average of languages spoken by each person was 3.04 (SD = 0.92). English was the most mentioned second language on both sites.

5.3 Activities involving multiple languages

When asked about the frequency with which they carried out digital activities in different languages, most responded that they did it often or very often (see Fig. 6 for details). Six common activities were provided as a reference, and an open question was available for participants' contributions. The activity of *watching/listening to media in different languages* was the one with the highest response rate of often/very-often in both sites: 81.9% at USI and 83.3% at PUCRS. This was also the only one in which responses from PUCRS often/very often exceeded those of participants at USI. The respondents in USI reported a higher frequency for the other five activities. This was particularly the case for *chatting/interacting with other users in different languages* and *contributing content in different languages for blogs, wikis, and social networks*,

[15] The Web Globalization Report Card is published yearly by the ByteLevel company (`www.bytelevel.com`).

[16] `Welie.com` is an UI pattern library built by researcher Martijn van Welie [Van Welie and Van der Veer, 2003]. The website was currently unavailable at the time of this writing.

[17] `UI-Patterns.com` is a website and pattern library made available by the web developer Anders Toxboe.

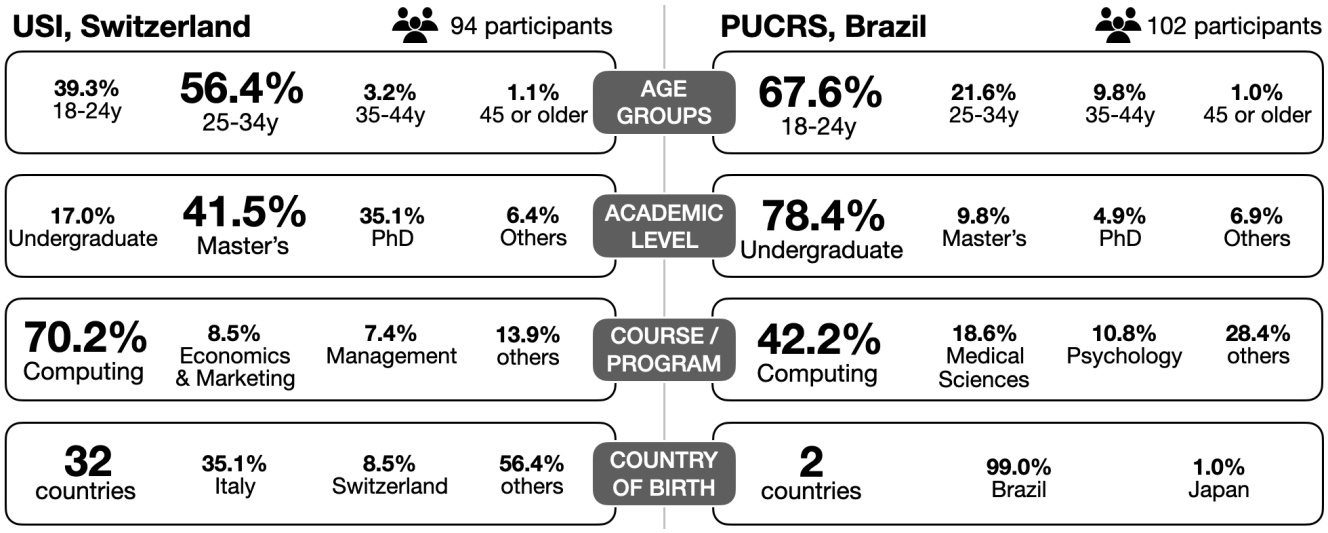

Figure 4. Demography of participants of the online survey.

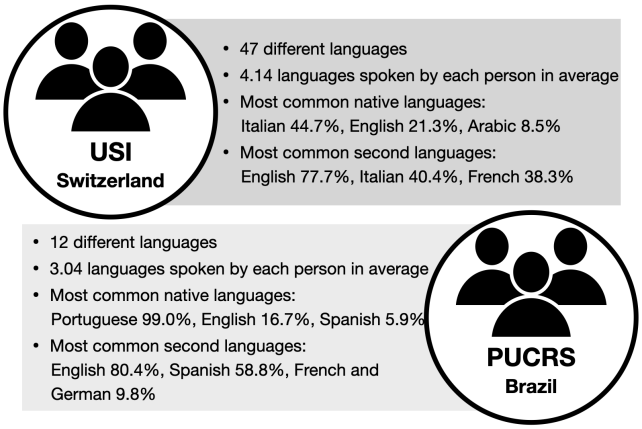

Figure 5. Language diversity among participants of the survey.

which were performed with almost double frequency: 66.0% to 37.3% and 33.0% to 17.6% respectively. This last activity (*contributing content in different languages*) was also the least frequent on both sites.

In the optional open question, some participants described other activities performed in different languages. The answers to this question contained a mix of activities performed in the digital and real world. The responses from USI reported the following activities (number of citations in parentheses when more than one): *making calls and having direct conversations* (6); *practicing sports* (3); *scientific/technical writing* (2); *shopping at supermarket/physical stores* (2); *playing videogames*; *listening to music*; *singing*; *teaching classes*; *attending classes*; *reading*; and *interacting with the government*. In PUCRS, the following activities were mentioned: *interacting with colleagues in the work environment* (5); *playing videogames* (4); *English learning* (3); *programming, bootcamps, hackathons* (2); *scientific research* (1); *teaching classes* (1); and *travelling* (1).

5.4 Problems faced by multilingual users

The last part of the questionnaire asked participants about problems faced while executing tasks in different languages. A list of 17 issues was presented to participants organized into four categories: *language configuration*, *reading*, *input/typing*, and *searching*. Participants should answer whether they had faced these problems at least once. Fig. 7 shows a summary of the answers, with colors indicating the rate of positive responses.

In general, respondents at USI reported a higher number of issues related to multilingual interactions. The difference between the responses of the two sites was especially remarkable for three of the issues. The first two are related to automatically detecting the user's region/language. *Automatic region detection leading to undesirable settings* was reported by 60.6% of USI participants against 35.3% at PUCRS. The situation of *advertisements being displayed in languages that the user does not understand* presented similar results (69.1% against 25.5%). The third issue with a remarkable difference was that of *physical keyboard not adapted to type texts in one of the user's preferred languages*: reported by 63.9% of USI participants and by 26.5% of those at PUCRS. Three issues were reported close to or above 70.0% in both sites: *badly translated software interface or web content*, *autocorrection feature incorrectly changing words*, and *spell check incorrectly highlighting words when typing texts in different languages*.

A final open question allowed participants of the survey in Switzerland (here identified as *P#CH*[18]) and in Brazil (here identified as *P#BR*[19]) to provide additional information about their experience regarding the interaction with computers in multiple languages. The response rate for this question was much higher among respondents at USI.

A recurrent complaint was the **difficulty of understanding websites/apps without a translation to English or one of their preferred languages**. Participant P8CH said that: *"Most of the problems I'm currently facing occur because of government pages that are in Italian, which make it extremely hard to gather necessary documents or fill out forms"*. P33CH said about the same issue: *"Sometimes, when I use some apps like grocery app, they don't have an option for the language I know and it is really hard for me to understand the product names and the offers"*. P63CH suggested English

[18] P stands for *participant* and CH is the ISO 3166 code for Switzerland.
[19] BR is the ISO 3166 code for Brazil.

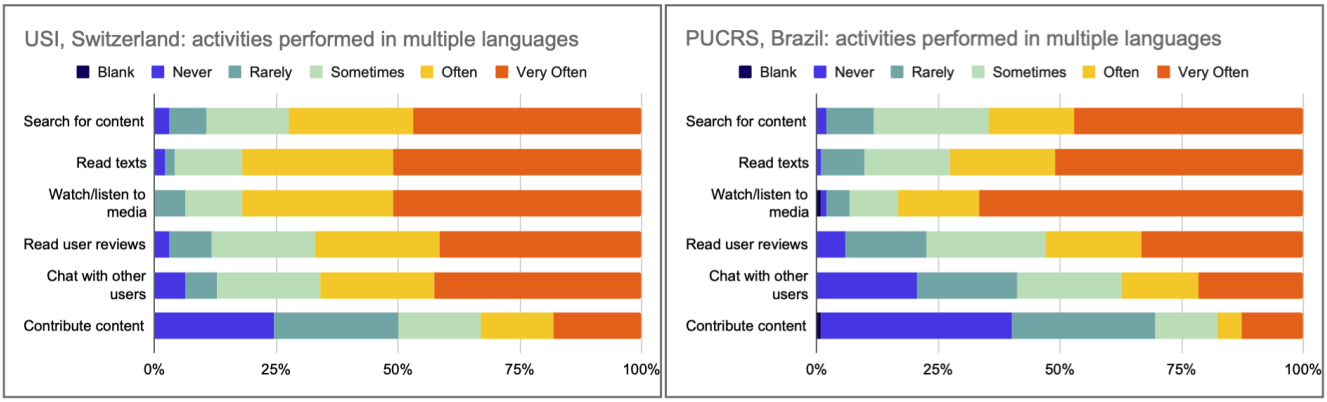

Figure 6. Frequency of engagement in digital activities involving multiple languages by participants from both universities.

Category	Issue	USI (Switzerland) %	PUCRS (Brazil) %
Configuration	Your preferred language was not available for selection in a specific system.	29.8	31.4
	It was difficult to find/identify the desired language from the selection list.	16.0	13.7
	Automatic detection of your region from the Internet connection led to undesirable settings.	60.6	35.3
	Other settings related to language (currency, date format, etc.) inconsistent with your preferences.	39.4	31.4
Reading	Badly translated software interface or web content.	75.5	73.5
	Content in different languages was hidden or difficult to access.	39.4	27.5
	Advertisements being displayed in languages that you do not understand.	69.1	25.5
	It was difficult to read/comprehend content in different languages.	31.9	23.5
	It was difficult to interact/chat with other users in different languages.	18.1	9.8
Input / Typing	Autocorrection feature incorrectly changing words when typing texts in different languages.	84.0	73.5
	Spell check incorrectly highlighting words when typing texts in different languages.	70.2	69.6
	Physical keyboard not adapted to type texts in one of your preferred languages.	63.8	26.5
	Problems to select/use the most appropriate virtual keyboard on a mobile device.	22.3	14.7
	Voice interfaces not recognizing speech in different languages.	31.9	26.5
Search	It was difficult to search content/websites in many languages using a single search.	40.4	37.3
	It was difficult to identify the language of the returned results.	6.4	10.8
	Most relevant results not appearing on top of the result list.	36.2	34.3

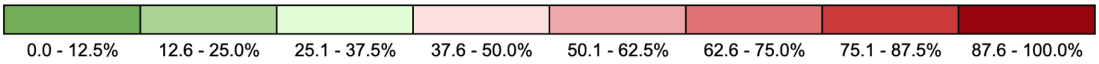

Figure 7. Issues related to multilingual activities faced by participants from both universities.

as a lingua franca to solve the problem: *"German and other websites not available in English ... I believe that basically every website should be available in English: it's 21st century already and people move around the world ... English is the most internationally used language"*.

More than one participant reported problems with **wrong language settings** in Switzerland. P49CH reported that: *"In Ticino way too often German is selected as default language for websites. Even big ones (e.g., Google, YouTube)."* Similarly, P76CH wrote: *"In Switzerland, it is a bit annoying that even if you are not in the German part (of the country), you might still get ads/content in German, rather than in French or Italian"*. P82CH reported the same issue: *"Especially with Microsoft's websites, the language is often set to German which, though I live in Switzerland, I don't understand at all ... same as ads on YouTube, often in German"*.

Another issue reported by users was related to **code-switching and -mixing**, the action of alternating between two or more languages in the context of a single situation. P73CH commented about that: *"When using voice-activated Cortana on Windows it would tab out my game when I cursed a Polish word ... because it sounded similar — negative, led to me uninstalling the voice assistant entirely"*. P52CH made another comment about code-switching: *"I often speak in multiple languages in the same context (English and Italian: English for the most part, Italian for 'reaction words')"*.

Three participants reported problems concerning **configuration, typing, and searching, in less common languages**. P18CH reported an issue with changing the current/default interface language to a preferred language: *"Some websites with infinite scrolling like to put the language selection in the footer ... it becomes difficult. Furthermore, where/how to change language settings is very inconsistent in different websites/applications, leading to loss of time and frustration"*. P49CH reported a difficulty with physical keyboards: *"Having US keyboard layout (laptop) I find it hard to add accents when writing in it ... on the other hand, on mobile devices it's very convenient"*. Finally, P8CH reported a situation with a heritage language: *"sometimes I would like to search something that I remember my grandma said or sang (I don't expect to find contents in my dialect, but Milan dialect is quite similar and more popular so I go for that), but I don't know*

how to write that, I just know how it sounds. It takes a lot to try all the possible combinations of letters".

Regarding positive experiences, **the usage of translators and dictionary tools** was cited by one participant at USI (P35CH: *"Browser or app translators help when sites or texts are not in languages I know"*) and one at PUCRS (P34BR: *"The Google Translate and eJOY AI Dictionary extensions are great and help me"*). The ability **to configure units of measurement independently of the default language** was mentioned by P3BR: *"A positive experience is being able to configure, on the same screen, weights and measures in units different from the default language chosen for the system. This helps to easily customize the system"*.

6 Design patterns: mapping current solutions

The final result of the patterns identification and organization is the pattern language represented by the network diagram displayed in Fig. 8. The 40 discovered patterns are shown grouped into five categories according to each pattern's main function or area of application. A full description of the pattern language development process and the comprising patterns can be found in Da Rosa [2024][20]. After discovery, the patterns were validated through two user studies: a focus group and a design workshop. In both cases, the participants were members of the PUCRS academic community.

In this section, we describe four of the patterns that are more closely related to some of the survey findings. Two of the patterns are related to the selection of a localized version of a website: GLOBAL GATEWAY and INTERFACE LANGUAGE SELECTOR. These patterns are at the core of the multilingual user experience and are closely related to issues reported at high levels by users such as *automatic region detection leading to undesirable settings*. The third pattern, MULTILINGUAL VIRTUAL KEYBOARD, is directly related to another large-scale problem reported by respondents at USI: *physical keyboard not adapted to type texts in one of the user's preferred languages*. The fourth and last pattern, MULTILINGUAL SEARCH RESULTS, is related to an issue that was reported with high rates by participants in both locations: *the difficulty to search content/websites in many languages using a single search*. The next sections contain detailed descriptions of each of these four patterns followed by reports of the validation procedures.

6.1 GLOBAL GATEWAY

Allow users to select a localized version of a website.

Context: A multinational company, usually selling tangible products, offers different localized versions of its website.

Problem: The user needs to choose the most adequate localized version of a website according to his/her location.

Solution: *Provide an interface (splash, menu, and/or dialog) for users to select one localized website from a list of options.* All the options in the interface should indicate the country/region of the localized website. Preferably, the options should also indicate the target language (together with the country/region). The GLOBAL GATEWAY is a key element of the *location-oriented* navigation model, that is, when the focus is on the country/region with language as a subset of that region [Yunker, 2010]. Fig. 10 shows a diagram of the GLOBAL GATEWAY pattern.

This pattern is typically implemented through three complementary UI widgets: a welcome splash page, a global gateway menu, and a location picker. The **international welcome splash page** is an optional welcome page usually shown on the user's first access. In case the user is accessing the localized website from a different country/region, a splash page asks whether he/she wants to keep loading that version or navigate to the version corresponding to his/her region. Some systems will detect the user's location (through Internet geolocation, browser configuration, etc.) and build the necessary message (including text in both languages is recommended). Other systems may simply display the location picker or may not have such a widget at all.

The **global gateway menu** displays the currently selected location and a button or link that fires the location picker. The selected location, accompanied or not by a selected language, can be written in full text or using typical ISO codes[21]. The button should contain a language-agnostic recognizable icon such as a generic globe[22]. This text/button pair can be positioned in the header or in the footer of the website pages. Current implementations vary, but placing it in the header will make it more visible and fit better on long scrolling pages.

Finally, the **location picker** is the dialog or overlay panel that displays all available pairs of location-language. When there are many options, countries/regions can be organized by continent to facilitate the selection. Country/region and language names must be written in the native language/script of that particular locale and can optionally also appear written in the current interface language. When both country/region and language names are available, usually country/region is displayed first and/or highlighted to indicate that location is the main focus.

Using flags to denote countries/regions within a GLOBAL GATEWAY is not technically wrong but can present some drawbacks: flag icons may occupy more space than plain text and do not scale well; flags display similar colors and shapes, making them difficult to differentiate; not all regions have an official flag; some flags may be disputed when that country/region is not recognized by other states. In general, flags are not recommended for the implementation of this pattern (for more information on this topic, see Ishida [2005]; Johansson [2006]; Jovanovic [2008]; Korpela [2016]; Yunker [2018b]; Sergushkin.com [2023]; and Offer [2024]).

Confidence rating: **

Known uses: This pattern is typical of websites of multinational companies such as 3M, Bosch, Nestlé, and Canon.

[20] A website containing a full description of the pattern language was available at the time of the original publication, but is currently down. We are working to make the website available again.

[21] Country codes are defined by ISO 3166, while language codes are defined by ISO 639.

[22] A generic globe icon is currently used in many websites to identify the global gateway button and is already recognized by many users Yunker, 2018a.

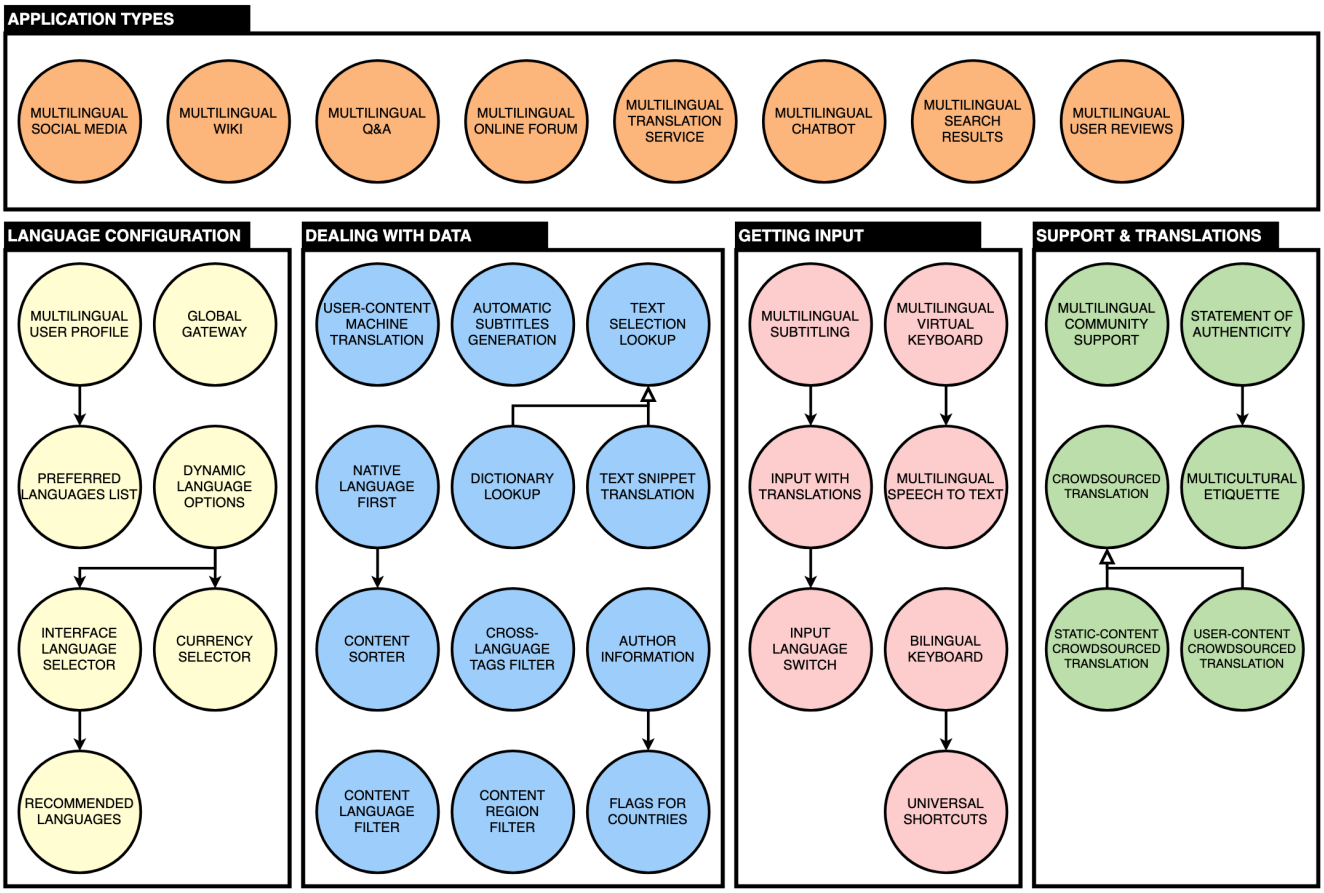

Figure 8. A pattern language of design for multilingualism: 40 HCI patterns developed from current systems.

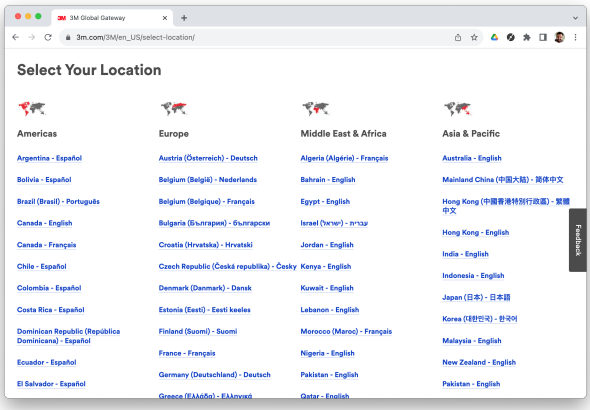

Figure 9. Illustration of GLOBAL GATEWAY as seen in the 3M website (Oct. 2023).

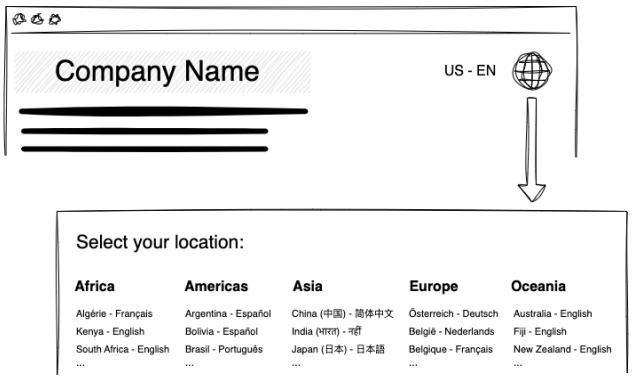

Figure 10. A diagram for GLOBAL GATEWAY.

References and related patterns: Yunker's book *The Art of the Global Gateway* describes this strategy in detail. Companies that are language-oriented can rely on INTERFACE LANGUAGE SELECTOR pattern instead.

6.2 INTERFACE LANGUAGE SELECTOR

Allow users to change the language of the system UI.

Context: A company or institution whose business does not depend on geopolitical borders wants to expand the reach of its website by providing translated versions in several languages. For example, this is the case for tourism companies in general (airlines, hotel chains, etc.), social media applications, and online service companies.

Problem: The user needs to find the translated version of the website that is best suited for him/her.

Solution: *Provide a widget with which the user can easily change the interface language at any time during the navigation.* When a small set of languages is supported, it is usually displayed in a drop-down list. Larger sets of languages can be displayed in a dialog or overlay panel. In the later case, suggestions for the most used and/or recommended languages may facilitate the user's choice. Most recommendations described for GLOBAL GATEWAY also apply to INTERFACE LANGUAGE SELECTOR, but a splash page is not as common for language-oriented websites. Some location-oriented applications based on GLOBAL GATEWAY may also offer language

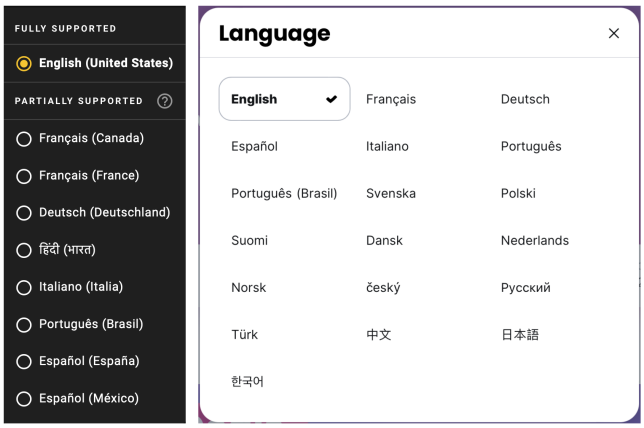

Figure 11. Illustration of INTERFACE LANGUAGE SELECTOR as seen in IMDb.com (a) and Hostelworld.com (b) (Mar. 2025).

selection for their users, but usually with only a small set of options (for example, a Swiss website that offers versions in German, French, Italian, and Romansh). Fig. 12 shows a diagram for the INTERFACE LANGUAGE SELECTOR pattern.

Language names should be written in the native language they represent, allowing users to navigate to the desired version even when they are viewing the interface in a language they do not understand. Language flavors or dialects specific to a country/region can be differentiated by appending the name of the country/region (for example, Brazilian Portuguese is typically presented as *Português (Brasil)*). Country flags do not represent languages and should be avoided. In addition to the reasons already mentioned in the description of GLOBAL GATEWAY, it is important to note that languages transcend country borders and many countries have more than one language. Therefore, using a country flag to denote a language is not only wrong but can also be offensive to many populations.

As soon as the system receives the command, it converts the entire interface to the selected language, typically reloading the web page. Changing the system language of a mobile device will also change the language of all running applications. This pattern can be combined with additional selectors allowing users to choose other language-sensitive preferences (most often, currency).

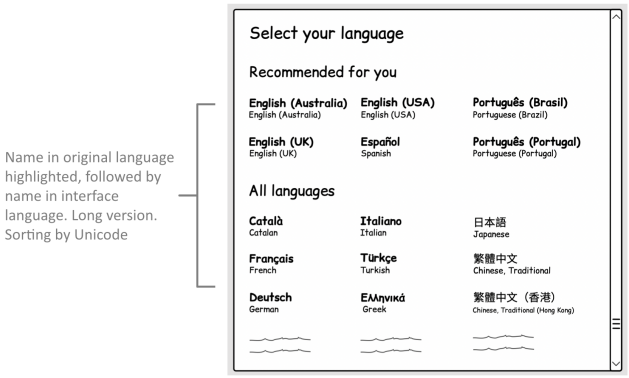

Figure 12. A diagram for INTERFACE LANGUAGE SELECTOR.

Confidence rating: ***

Known uses:: This pattern can be found in websites such as Booking.com, Hostelworld.com, YouTube, and IMDb.com.

6.3 MULTILINGUAL VIRTUAL KEYBOARD

A virtual keyboard that allows text input in multiple languages.

Figure 13. Illustration of MULTILINGUAL VIRTUAL KEYBOARD as seen in Google Gboard for Android 11 (Feb. 2022).

Context:: A platform or software application that allows input of text based on the Unicode Standard[23].

Problem:: Multilingual users need to input text in different languages and varying scripts, a very complex task using monolingual or bilingual keyboards.

Solution:: *Provide a virtual keyboard on screen that supports text input in many languages and scripts.* This is the typical input method for devices based on touch screen (smartphones and tablets) and remote control (smart TV). Fig. 14 shows a diagram for the MULTILINGUAL VIRTUAL KEYBOARD pattern.

The virtual keyboard is shown on the device display containing the necessary keys to type in the selected language. Interaction with the keyboard is usually performed through the touch screen, but can also happen through a pointing device such as a computer mouse, a remote control or a gaming controller.

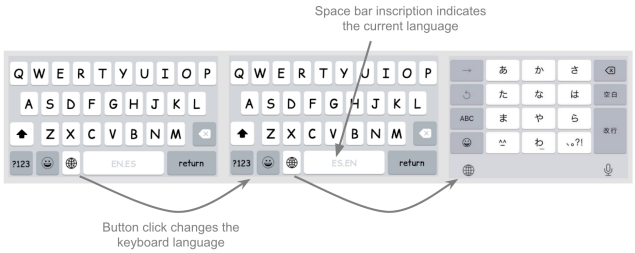

Figure 14. A diagram for MULTILINGUAL VIRTUAL KEYBOARD.

The language can be switched according to the user's needs. A button with a generic globe icon is currently recognized as the standard sign for the action of changing the keyboard language. By tapping the button, the user can choose a different language and the keyboard will adapt its layout accordingly. The virtual keyboard must inform to the user which is the selected language at each moment. Some implementations use the area of the space bar to display this information.

When changing between languages that use the same script, the most common adaptations are: showing and hiding letters; showing frequently used letters with diacritics; and changing the position of letters. For languages that use completely different scripts, the keyboard may radically change its layout to adapt to the selected language.

Confidence rating: ***

[23] Unicode is a standard designed to support the digitization of text in all of the world's writing systems. The standard has near-universal adoption.

Known uses:: This pattern is implemented by virtual keyboards of mobile platforms, such as Google Gboard, Microsoft SwiftKey, Samsung Keyboard, and iOS onscreen keyboard. It is also present on some desktop systems, such as macOS which implements it through its *Accessibility Keyboard*.

6.4 MULTILINGUAL SEARCH RESULTS

A result list including items in multiple languages.

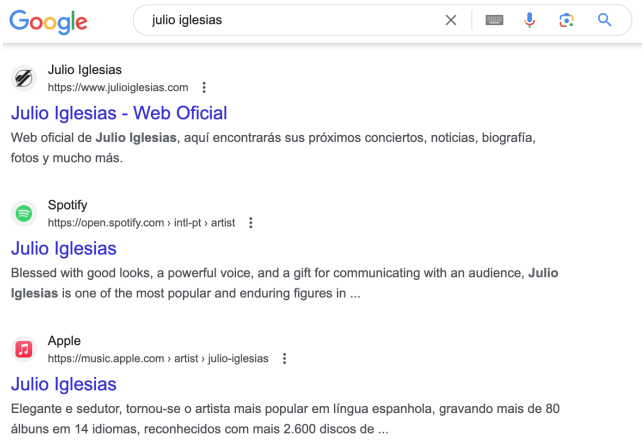

Figure 15. Illustration of MULTILINGUAL SEARCH RESULTS as seen in Google Search (Oct. 2023).

Context: Web search engines or other information retrieval applications dealing with multilingual information.

Problem:: Users of a search engine need to find the most relevant results after searching a multilingual base of information.

Solution:: *Provide a list of results including all relevant items, regardless of the language in which the results are written.* The exact order of the results will depend on the recommendation algorithm adopted by the search engine. Fig. 16 shows a diagram for the MULTILINGUAL SEARCH RESULTS pattern.

Features such as language and region filters allow users to refine the results and find the most relevant items. Google Search and Microsoft Bing seem to put a stronger emphasis on results written in the interface language chosen by the user. In that case, most top results will be in the user's language. These two engines offer very limited filtering options (Google will only provide two options for language filtering: *pages in any language*—the default—or *pages in the current interface language*). DuckDuckGo, in turn, puts less emphasis on language and ranks results following other criteria. This engine offers a filter by region/language, facilitating the navigation through the result list.

Confidence rating: *

Known uses:: Web search engines Google Search, Microsoft Bing, and DuckDuckGo provide MULTILINGUAL SEARCH RESULTS. Among these, DuckDuckGo is the only one that offers a filter by region/language.

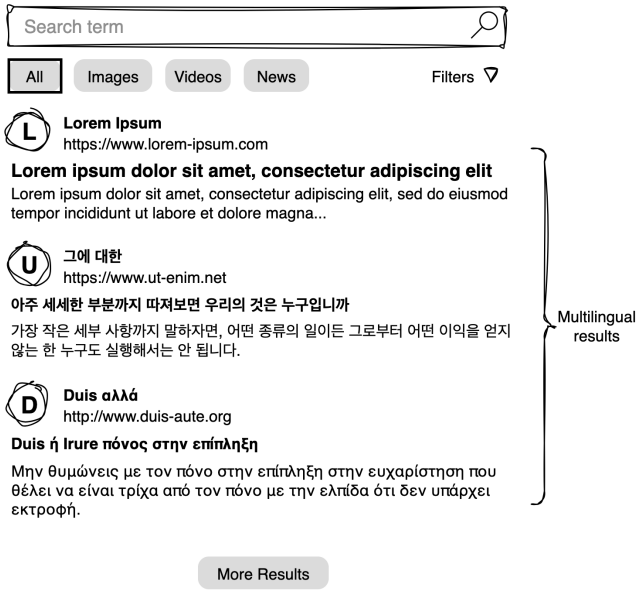

Figure 16. A diagram for MULTILINGUAL SEARCH RESULTS.

6.5 Patterns validation: Focus group

To validate the language from the point of view of experienced professionals, a focus group was planned and conducted. The procedure was adapted from the guidelines for interviews and focus groups in the context of HCI as described by Lazar *et al*. [2017]. In this setting, the typical focus group structure was combined with elements of a design workshop, which is a common form of HCI patterns validation [Da Rosa and Silveira, 2022].

Table 2. Characterization of the participants in the focus group.

Code	Age (years)	Degree	Occ.[a]	Exp.[b] (years)	Lang. skills[c]
PFG1	18-24	Master's	Software Developer	4	pt, en
PFG2	25-34	PhD	Software Developer	10	pt, en
PFG3	25-34	Master's	IT Professional	11	pt, en
PFG4	35-44	Master's	Systems Architect	20	pt, en, es
PFG5	35-44	Master's	Designer	20	pt, en, es

[a]Occupation
[b]Experience
[c]Language codes: pt = Portuguese, en = English, es = Spanish.

Participants were recruited among students from the PUCRS graduate program who had a minimum of 4 years of professional experience in computing, design, or related areas. Table 2 shows a characterization of the five participants who attended the focus group, henceforth identified as *PFG#*, where "PFG" stands for *participant of the focus group* and "#" is a unique code attributed to each participant to ensure anonymity. All participants had intermediate to advanced knowledge of software development and at least a basic understanding of design patterns, except PFG5, who had little experience in software development but advanced knowledge of design patterns.

The group was held in person at PUCRS' premises. All

participants had a personal smartphone and laptop computer at their disposal. Paper sheets (A4 size) and pens were distributed to each member of the group. The meeting took 90 minutes (1.5 hours) and was divided into four stages: an introduction to the research project; an initial presentation of the pattern language; the development of a design task followed by the group interview; and a closure including a final questionnaire. Asking the participants to develop a design task during the activity was a strategy to make them interact more profoundly with the presented patterns.

The group was conducted by one facilitator and supervised by a second researcher. At the beginning of the meeting, the facilitator introduced the research project and explained the basic activity structure. After the informed consent, all participants received a demographic questionnaire and a printed sheet of paper containing: the network diagram of the pattern language, the full address of the language website, and a QR code for the same web address. With the QR code, participants could access the language website, which contained detailed information about each pattern. The facilitator then started a presentation of the pattern language. Next, the facilitator proposed the following scenario and design tasks to the participants:

- *You have been requested to design an interface to show the list of user reviews of a product on an e-commerce website. The text of each review might have been written in any language and should be accessible to all visitors of the website.*
- *Considering the pattern language that has just been presented, which of the patterns could be applicable in this context?*
- *How could each pattern be useful in the design of the proposed interface?*
- *Try using the patterns whenever possible and make sketches to illustrate your ideas.*

Participants were given around 20 minutes to conclude the proposed task. They were encouraged to take notes and make drawings on the sheets of paper. After the agreed time for the task, a semi-structured group interview was conducted by the facilitator. Participants answered general questions about their experience and their perception of the pattern language. The researchers took notes as the interview unfolded. A final evaluation questionnaire was distributed and the group members had around 10 minutes to answer it and return all forms and sheets to the facilitator.

All participants of the focus group made sketches of their proposals for the design, except PFG5, who preferred to take notes on the computer. Fig. 17, in Appendix 2, presents some of the sketches made by the participants. PFG1 and PFG3 used arrows to identify the corresponding design patterns applied in their drawings (Fig. 17 (a) and (b)). PFG2 and PFG4, in turn, used numbers close to the design elements and then wrote down lists with the corresponding pattern names (Fig. 17 (c) and (d)). PFG1 and PFG4 mentioned five patterns, while PFG2 and PFG3 mentioned six patterns of the language in their diagrams. The simplicity of the drawings was understandable given the short duration of the activity. It was remarkable, however, the agility of the participants in sketching their solutions and the way they managed to associate the patterns with the elements used in the design process.

During the group interview, participants commented about their previous experience with patterns. PFG2 and PFG3 remarked that the activity made them **recognize or remember patterns** that they *"did not recognize as patterns before"* or *"had forgotten about"*. Other participants had **previous experience with patterns in specific contexts**: PFG3 only knew the *"Google's developer guidelines for Android"* and PFG4 *"as a developer/architect, ... only knew the design patterns (in Software Engineering), not in HCI"*.

When asked about their understanding of the pattern language from the presentation given, all five participants agreed that they **had satisfactorily understood the pattern language**. PFG2 said that *"it was simple to comprehend and the examples help a lot in understanding the concepts"*, to which PFG3 added *"my knowledge on the subject was significantly expanded"*. PFG4 responded: *"I gained new insight into a hitherto unknown topic"*. Next, participants were asked whether the pattern language helped with the design task. All participants reported that **the pattern language was helpful** to perform the task. PFG1 said that *"it helped considerably"* and that *"it was possible to identify patterns within the imagined functionalities"*. PFG2 considered that *"it helped, especially with the examples shown"* and *"the pattern language is quite complete"*. PFG3 remarked that *"it would be impossible to carry out the task without it"* and PFG4 said that *"it became easier to think about the elements and their representation"*. Finallly, PFG5 agreed: *"(It helped) a lot. It is easier to understand and apply when there are patterns"*.

As **suggestions for improvement**, PFG1 pointed out the *"necessity of some higher level patterns for the Dealing With Data (category)"*. PFG2 suggested *"a visual representation of each pattern, to make understanding even easier"*, even though the website contained diagrams and illustrations for most of the patterns (but not all).

The answers to the final evaluation questionnaire can be seen in Table 3. All five participants agreed or strongly agreed that **the patterns were easy to find** within the language (Question 1). Regarding the quality of the patterns (Question 2), all participants evaluated that **the pattern descriptions were of good or excellent quality**. The last question was an open question in which users could provide their impressions on the potential of the pattern language (Question 3). All professionals praised the **potential of practical application** observed for the patterns, using words such as *"viable"*, *"useful"*, and *"relevant"* (see Table 3).

6.6 Patterns validation: Design workshop

A second study was conducted to validate the language from the point of view of beginner developers. This activity was structured as a design workshop. The procedure described by Sauppé and Mutlu [2014], who conducted design sessions to validate their pattern language for human-robot interactions, was used as a reference.

Participants were recruited among PUCRS undergraduate computing students with little or no professional experience. The objective was to validate the patterns from a second point of view, simulating the contact that less experienced

Table 3. Evaluation of the pattern language by participants of the focus group.

Part.	**Question 1:** Whenever necessary, it was easy to find patterns within the language.[24]	**Question 2:** How do you evaluate the quality of the pattern descriptions?[25]	**Question 3:** How do you assess the potential for these patterns to be applied in practice?
PFG1	Strongly agree	Good quality	*"Lots of potential for use within the proposed context."*
PFG2	Strongly agree	Excellent quality	*"They can be very useful in building a system, as a guide in application development."*
PFG3	Agree	Excellent quality	*"Highly relevant."*
PFG4	Strongly agree	Excellent quality	*"Very relevant (as seen by someone who had no prior knowledge)."*
PFG5	Agree	Excellent quality	*"Totally viable."*

Table 4. Characterization of the participants in the design workshop.

Age groups	18-24	21 pers. (72.4%)
	25-34	8 pers. (27.6%)
Study & work	Just studying	6 pers. (20.7%)
	Studying and working	23 pers. (79.3%)
Occupations	Software developer	12 pers. (41.4%)
	IT Professional	4 pers. (13.8%)
	Support technician	3 pers. (10.3%)
	Other IT professions	4 pers. (13.8%)
Professional experience	Average experience[a]	1.8 years (SD = 1.74)
Bilingualism	Average number of spoken languages	2.93 lang. (SD = 0.88)
Spoken languages	Portuguese (pt)	29 pers. (100.0%)
	English (en)	29 pers. (100.0%)
	Spanish (es)	13 pers. (44.8%)
	German (de)	6 pers. (20.7%)
	Others (fr, it, ja, ru, cmn)[b]	6 pers. (20.7%)

[a] Including those with no (zero) experience.

[b] Language codes: fr = French, it = Italian, ja = Japanese, ru = Russian, cmn = Mandarin Chinese.

professionals might have with the language in settings such as participatory design sessions or multidisciplinary teams meetings. A total of 29 participants attended the workshop and their characterization is shown in Table 4. All participants were enrolled in a computing undergraduate course (Computer Science, Software Engineering, etc.) and five participants had a previous bachelor's degree in other areas.

All participants had a personal smartphone at their disposal and some participants, but not all, had also a personal laptop. The meeting took 90 minutes and was divided into four stages: an introduction to the research project; an initial presentation of the pattern language; the organization of the participants into groups and the development of a design task within the groups; and a closure including a final questionnaire.

To provide an easily accessible visual representation of the patterns, a kit was prepared to be handed to each group in the beginning of the third stage. The kit contained a paper sheet with the network diagram of the pattern language printed on it and a deck of 40 cards, each of them containing summary information about one of the patterns (see Fig. 18 in Appendix 2). The usage of cards to represent patterns in a user study can be observed in works such as Wania and Atwood [2007]; Athvankar *et al*. [2014]; Khambete *et al*. [2015]; Mitchell and Boer [2017]; Bach *et al*. [2018].

Following the recommendation of Athvankar *et al*. [2014], the front face of the cards contained the name, summary, and diagram of the patterns. The front face also had a background color and an icon indicating which of the five categories the pattern belonged to: *Application Types* (orange), *Language Configuration* (yellow), *Dealing with Data* (blue), *Getting Input* (red), or *Support and Translations* (green). The back face of the cards contained known uses, an illustration image, and information about related patterns. Our goal with the cards was to provide to the participants with a tangible representation of the patterns in a way that the interaction within the groups could be facilitated. Moreover, the paper sheet with the complete language diagram contained a web address and a QR code, so that participants still could access more detailed descriptions of the patterns on the website.

The workshop was conducted by one facilitator. The first and second stages followed a structure similar to that of the focus group described previously (see Section 6.5). In the third stage, participants were organized into six groups of approximately five people and each group received one kit containing the language diagram and the deck of pattern cards. The researcher proposed the following scenario and design

tasks to the groups:

- *You are working on the design of a website/app called* Boca-a-Boca *(Word of Mouth): a social network in which users can publish recommendations of movies, digital games, music, tourist attractions, restaurants, etc. It must be aimed at an international audience and must be adapted to users with different levels of multilingualism.*
- *Each group will receive a task related to the design of a feature of the application. Each group will also receive a deck of cards with information about the patterns.*
- *Considering this task description and the pattern language that has just been presented, which of the patterns could be applicable? How could each pattern be useful in the design of the proposed interface?*
- *Try referring to the patterns whenever possible and make sketches on the paper to illustrate your ideas.*

Four different design tasks had been planned in advance and a brief description of each of them was printed on small pieces of paper. Each task was related to one of the main categories of the pattern language (*Language Configuration*, *Dealing with Data*, *Getting Input*, and *Support and Translations*). The first two tasks were printed twice. The participants were not informed about the association between task and category, and they were allowed to use any of the patterns in the language. These were the task descriptions distributed to the groups:

- **Task 1** (*Language Configuration* — Groups 1 and 2): *Within your group, discuss how the design of user profile settings on the proposed social network could be done. How would the settings related to the user's region and languages be like?*
- **Task 2** (*Dealing with Data* — Groups 3 and 4): *Within your group, discuss what features there could be for reading posts and comments on the proposed social network (also consider video consumption). What would it be like to read content in other languages?*
- **Task 3** (*Getting Input* — Group 5): *Within your group, discuss what features there could be for writing content (posts, comments, videos, etc.) on the proposed social network (also consider video consumption). What would content production be like in different languages?*
- **Task 4** (*Support and Translations* — Group 6): *Within your group, discuss what resources there could be for a help system and a collaborative translation system on the proposed social network. How would interaction be like between users of different languages in the help and translation systems?*

Participants had around 20 minutes to discuss the design task within their groups. All groups based most of their discussion on the provided cards: some of the groups also took notes, but no group made any sketches on paper. After that, a member elected by each group briefly presented the solutions to all participants (see Fig. 18 in Appendix 2). For the presentation of the results, participants once again used the cards to illustrate their solutions. All groups correctly identified the category and color of the cards to which their task was most related. Fig. 18(a) shows a member of Group 1 presenting part of their results after discussing Task 1: *"Offering GLOBAL GATEWAY and DYNAMIC LANGUAGE OPTIONS to allow the easy selection of the interface language"*. Fig. 18(b) and (c) show the spokesperson of Group 2 presenting their solution for the same task: *"Combining MULTILINGUAL USER PROFILE, PREFERRED LANGUAGES LIST, and INTERFACE LANGUAGE SELECTOR for a good trade-off between language settings and language selection"*. Fig. 18(d) shows the cards over the table of Group 3 while they discussed Task 2.

As a final step, each participant of the design workshop individually answered an evaluation questionnaire regarding the activity. Participants are henceforth identified as *PDW#*, where "PDW" stands for *participant of the design workshop* and "#" is a unique code attributed to each participant to ensure anonymity. Most participants declared having little or no previous knowledge of HCI patterns (Question 1), but all of them affirmed that they had satisfactorily understood the pattern language after the initial presentation (Question 2). About this, PDW5 stated: *"I found it to be a very complete presentation, covering the techniques in a way that people who are not in the UX area can understand"*.

When asked whether the pattern language had been helpful (Question 3), 28 participants (96.6%) stated that **the language had helped during the development** of the design task, and only one participant left blank. The participants highlighted different aspects of the pattern language usage: **introducing the design problem** (PDW4: *"before the presentation, I would not have made some important connections"*, PDW10: *"it provided a good foundation of concepts"*, PDW21: *"we started from a pre-established base"*); **simplifying the design** (PDW13: *"these patterns shaped the ideas, directing them towards plausible solutions"*, PDW18: *"it facilitated the transition from ideas to paper"*, PDW29: *"clearer ideas for interfaces"*); **structuring the design process** (PDW5: *"it helped to understand the user needs"*, PDW6: *"by providing proven solutions, it allows for an efficient structured approach to creating interfaces"*); **improving productivity** (PW17: *"knowing the patterns mainly helped with the speed of the design task"*, PDW23: *"we didn't have to think everything from scratch"*); and **assisting with communication** (PW27: *"the patterns helped everyone speak the same language"*).

Table 5 summarizes the responses for questions 4 and 5 of the questionnaire. In general, participants evaluated the patterns positively. Regarding the task of finding patterns within the language during the design activity (Question 4), 86.2% of participants agreed or strongly agreed that **the patterns were easy to find**. The same number of participants approved the quality of the patterns (Question 5), evaluating that the pattern **descriptions were of good or excellent quality**.

Question 6 was an open question regarding the potential for the patterns to be applied in practice. Except for one participant that left it blank, all other participants evaluated this potential positively. In some of the responses, participants highlighted aspects such as **inclusivity** (PDW4: *"good potential to assist the development of bilingual projects."*, PDW5: *"(they are) very applicable, because currently, with the advancement of technology, this also diversifies user profiles, and all applications need to be prepared to receive them"*); **easy communication** (PDW7: *"easy exchange of*

Table 5. Assessment of the pattern language by participants of the design workshop: responses to questions 4 and 5 of the evaluation questionnaire.

Question	Response	N. Part.	%
Question 4: Whenever necessary, it was easy to find the patterns within the language.	Strongly agree	8	27.6%
	Agree	17	58.6%
	Neutral / Undecided	4	13.8%
	Disagree	0	00.0%
	Totally disagree	0	00.0%
Question 5: How do you evaluate the quality of the patterns descriptions (accuracy, completeness, consistency, comprehensibility, etc.)?	Excellent quality	11	37.9%
	Good quality	14	48.3%
	Average quality	4	13.8%
	Bad quality	0	00.0%
	Terrible quality	0	00.0%

knowledge"); **plausibility** (PDW13: *"they all seemed plausible"*); and **practicality** (PDW25: *"good, because they are very practical patterns and used in everyday life"*).

A final open question allowed participants to provide any other type of feedback (Question 7). PDW4 questioned the authenticity of the patterns: *"I was in doubt about the authenticity"*. PDW5 commented about an important aspect related to **accessibility**: *"I found very interesting the person who is fluent in a language but has difficulty with literacy and I had never thought about that aspect — when we think about accessibility in interfaces, the most diverse aspects must be considered"*. PDW13 concluded that the discussion yielded by the activity was *"a fundamental and interesting topic"*.

The validation process discussed in this section followed recommendations from Da Rosa and Silveira [2022] and stands as a first assessment of the proposed pattern language. The validation procedures with experienced and beginner students/professionals yielded an approval of the patterns regarding the findability, effectiveness, and feasibility criteria. The obtained results also point to good levels of reliability and plausibility, however, more studies to better assess these latter two criteria are recommended.

7 Discussion

The presented results are an initial step in understanding the needs and issues faced by multilingual users when interacting with digital devices. Due to the nonprobability sampling, the results from the survey cannot be generalized to all technology users and not even to the academic communities of the target universities. However, comparing the outcomes from the two locations can still produce valuable insights.

In this section, the results are synthesized, discussed, and contrasted with the design patterns described in Section 6. Some findings can inform future design projects or spark new research initiatives. The discussion also brings to light challenges and opportunities in researching the intersection between multilingualism and HCI.

7.1 Design for multilingualism

The high multilingualism of the sampling is aligned with other studies that indicate a high rate of multilingualism among the world population in general [Grosjean, 2010; Tucker, 1998; Wei, 2000]. These high rates were already expected for a population of university members, most of them enrolled in computing courses. Nonetheless, the high number of participants reporting skills in four or more languages is worth noting, especially at USI. There is also a high rate of multilingualism among PUCRS' respondents, despite the wide dominance of Portuguese as Brazil's education and national language (most courses at PUCRS are taught in Portuguese).

Societal multilingualism implying individual multilingualism, which had already been observed by linguists [Cenoz, 2013], can also be observed by comparing the samples. Southern Switzerland is a highly multilingual region of a traditionally multilingual country. In addition to that, USI has a culture of intense internationalization. The region in which PUCRS is located in Brazil is comparatively less multilingual and the university does not receive as many international students. These are probable causes for participants in USI who have a higher level of individual multilingualism.

Among USI participants, it is possible to identify multiple nationalities and a myriad of native languages. Furthermore, the second languages reported by USI participants are most relevant to studying, living abroad, or interacting with neighboring cultures (English, Italian, French, etc.). At PUCRS, it is possible to identify a great majority of Brazilian participants, Portuguese as the widely dominant native language, and a few second languages that are most relevant for studying/working in the South American context (English and Spanish).

It is also possible to observe that multilingualism affects behavior in the digital world, since participants reported high rates of online activities carried out in multiple languages. The frequency of these activities was also higher at USI, an environment with higher levels of societal and individual multilingualism. This indicates that the multilingualism of everyday life is also reflected in digital activities.

By indicating that higher levels of societal and individual multilingualism do impact the behavior and problems faced by technology users, the study reinforces the call to consider multilingual users during the design process of interactive systems. Adopting a more dynamic notion of multilingualism, such as plurilingualism, is also indicated as users reported switching and mixing languages during a single interaction. Design strategies might have to be rethought considering this perspective. Although some software applications have a certain level of adaptation to multilingualism, the analysis of

current systems showed that many solutions still lack standardization. Many implementations of GLOBAL GATEWAY and MULTILINGUAL SEARCH RESULTS, for example, still vary considerably.

7.2 Support different types of multilingualism

Different types of multilingualism can be observed by comparing the multilingual activities reported by the participants of the two universities. Participants in PUCRS reported a higher rate for *watching/listening to media in different languages*, which indicates a high consumption of international media content in Brazil. In contrast, participants in USI reported higher rates in all other activities and much higher rates for *chatting/interacting* and *contributing content in different languages*, which is expected for people in a more multicultural context. In the open question for reporting other multilingual activities, participants in USI mostly reported offline routine activities typical of foreign students living abroad (*direct conversations*, *practicing sports*, *shopping at the supermarket*, etc.). The respondents in PUCRS, in turn, mainly reported work-related activities (*interacting with colleagues*, *English learning*, *programming*, etc.), which are more related to multinational work environments.

Regarding the problems reported by the participants, it is possible to identify similarities and differences between the two locations. Three items were marked at similarly high rates at USI and PUCRS (*badly translated software*, *spell checkers*, and *autocorrection*). These issues may be related to multilingualism in general. On the other hand, some items were reported at much higher rates by participants from USI. Above 60% of the respondents in USI reported issues related to *undesirable language settings/auto-detection*, *advertisements in incomprehensible languages*, and *unadapted physical keyboards*. Participants in Switzerland also used the open question to report problems such as websites lacking an English translation and German being automatically selected as the default language, even for Italian-speaking users. These issues may be related to the increased multilingualism in Switzerland and are further discussed in the following sections.

The study shows that the type of multilingualism can vary from region to region and have its own nuances. Research with native English speakers is still needed and relevant, but it will capture only a particular point of view. Individuals in multilingual societies, such as Switzerland, tend to be more multilingual and present different behaviors and difficulties. Furthermore, research with users from other linguistic contexts is also welcome to advance knowledge on the topic, including people from peripheral and semi-peripheral countries, underrepresented populations, indigenous peoples, signing communities, language minorities, refugees, low-literate and illiterate, etc. In these contexts, language-related issues can affect the interaction design process, just as design decisions can influence language use and practices. Including the use of language as a design space element of inclusive Human-Computer Interaction may be critical to improving the user experience of these often marginalized populations and helping preserve endangered languages and the world's cultural heritage.

7.3 Flexible language configuration

Providing a flexible and effective language configuration can be challenging when multilingual users are considered. Many survey participants, especially in Switzerland, complained that the interface language was wrongly detected based on the IP address of their internet connection. In particular, users from the Italian-speaking region of Switzerland had to deal with websites and advertisements constantly displaying in German, even though it was a language that they could not comprehend.

The HTTP protocol and most web browsers allow the configuration of a list of preferred languages[26]. However, many websites around the world still ignore it, prioritizing Internet geolocation to define the default interface language. It is not unusual nowadays for users to redundantly configure language preferences in multiple levels of the software stack (operating system, web browser, web application, etc.) and still receive content in an unwanted language.

A second challenge regarding language configuration is to provide a proper mechanism for users to select the desired localized version of a website. Patterns GLOBAL GATEWAY and INTERFACE LANGUAGE SELECTOR are examples of such mechanisms. Despite the possibility of identifying emerging patterns in current websites, there is still a lot of inconsistency in implementations of GLOBAL GATEWAY. One of the survey participants complained about websites that position the language selector at the bottom of pages with a long scrolling, for example, making it difficult to find.

In contexts of high multilingualism, websites allow for the configuration of other language-related preferences. For instance, accommodation and airline websites often feature widgets for selecting currency alongside INTERFACE LANGUAGE SELECTOR. A survey participant praised the possibility of configuring units of measurement regardless of the chosen language.

7.4 Displaying multilingual information

Providing a good range of localized interface versions is essential to ensure access to the software by as many users as possible. However, localization has its own inherent challenges as it is usually a complex and expensive task. Badly translated interfaces were one of the problems reported at higher rates by survey participants. Participants also complained about websites that did not have translations in a local language or in English. Translation crowdsourcing and community localization are alternatives used to take advantage of the multilingualism of the user base and avoid the costs of professional translations and outsourced localization (see, for example, the successful translation projects of Wikipedia [McDonough Dolmaya, 2017] and Facebook [Lenihan, 2011; Scannell, 2012]).

In addition to providing enough interface translations, designers should also provide adequate access to content generated by international users. The survey participants in both universities reported reading texts, user reviews, and other user-generated content in multiple languages. Automatic

[26] HTTP, since version 1.0, provides the *Accept-Language* request header and the *Content-Language* response header for language negotiation.

translation and dictionary tools can be useful in facilitating access to content in languages that the user does not comprehend, as reported by two participants. Recent advances in machine translation (including the use of large language models and generative artificial intelligence) are promising [Kocmi *et al*., 2023] and could directly impact the user experience.

Regarding the pattern language presented in this work, the patterns in the categories *Application Types* and *Dealing with Data* capture current strategies for the display of multilingual information. MULTILINGUAL COMMUNITY SUPPORT and CROWDSOURCED TRANSLATION describe strategies to utilize a participatory user base to offer lower-cost support and translations.

7.5 Input and typing in all languages

Allowing the entry of written and spoken information in as many languages as possible is a challenge when designing for multilingualism. Issues related to spell checkers and text autocorrection were among the problems survey participants reported at the highest rates. Users frequently type using idioms, acronyms, abbreviations, code-switching, code-mixing, etc., and apparently most spell checkers and autocorrection tools are not ready to deal with all this diversity.

Another problem reported in our survey was unadapted physical keyboards. Multilingual participants from Switzerland complained about difficulties typing texts in multiple languages with mechanical keyboards. Most physical keyboard models are monolingual, and only a few models are bilingual. Typing using these keyboards can become very difficult if the desired language is not one of the two languages supported by the device. In contrast, MULTILINGUAL VIRTUAL KEYBOARD in mobile devices are much more flexible, allowing text input in hundreds of languages, as one participant attests.

Considering that voice interfaces are not as widespread as other mentioned technologies, the number of participants who reported problems with these tools is remarkable. In the commentaries, one participant reported an issue with a voice assistant misinterpreting speech containing mixed languages. Devices aimed at multilingual text and voice input are a good topic of research.

7.6 Effective unbiased search of multilingual content

Multilingual searching has been a topic in the area of Information Retrieval for many years[Steichen and Freund, 2015; Chu and Komlodi, 2017; Ling *et al*., 2018; Steichen *et al*., 2024], but most web search engines changed very little over the same period. One of the issues reported at high rates by the survey participants was the difficulty of searching websites in many languages using a single search. One participant also reported problems searching content written in a heritage dialect. Pattern MULTILINGUAL SEARCH RESULTS could be identified in most search engines, but only DuckDuckGo provided a more precise filter by country/language. Providing more control to the user on filtering and sorting the search results could solve some of the reported problems.

7.7 Users' behavior, interaction patterns and the impact on HCI design

The online survey reported in this article was conducted as a complementary study within the context of a broader research project aimed at proposing a new pattern language and analyzing its impact on HCI design. By detailing user behavior and their common problems, it informs the development of the patterns, confirms some of the assumptions adopted at the beginning of the process, and ultimately influenced the consolidation of the pattern language in its final version.

The proposed pattern language was used successfully by information technology (IT) students/professionals to debate design tasks and support design decisions during the validation studies. Experienced professionals discussed the language in a focus group and produced sketches of an interface for displaying user reviews on an e-commerce website. Students with little professional experience engaged in discussions on the design of a social network using cards that contained information about the patterns. In summary, the pattern language served as a specialist technical lexicon, allowed beginner and experienced professionals to engage in the design process, and provided rationale for design decisions. All these qualities of the patterns can help to develop websites and applications that take into account the issues of multilingualism and linguistic diversity. Software interfaces fully adapted to multilingualism tend to ensure a more accessible and culturally sustainable HCI design.

8 Conclusion

Multilingualism gained visibility with globalization, increased mobility, and super-diversity. Nevertheless, studies focusing on users' needs and consequent impacts of multilingualism on interaction design are incipient or nonexistent. This paper presented an investigation of the behavior and difficulties reported by multilingual technology users in two different linguistic contexts. Data were collected through an online survey applied to the academic communities of USI, in Switzerland, and PUCRS, in Brazil. In an extension of the original study, a pattern language is presented highlighting the four patterns that are most related to the survey results. Analysis of the results allowed us to confirm previous assumptions regarding multilingual software users and identify challenges and opportunities in multilingualism and HCI research. This section presents final considerations, proposals for future work, a brief discussion on the limitations of the study, and ethical considerations.

8.1 Final considerations and future work

The survey results are coherent with previous language-related assumptions, such as the high levels of multilingualism, societal multilingualism implying individual multilingualism, and multilingualism being transposed into the digital world. Common problems related to multilingualism and HCI were identified, some specific to the more multilingual USI environment. Differences between the responses from the two universities also indicate that different linguistic communities

face different difficulties when interacting with digital systems. Design patterns developed through analysis of current systems demonstrate that recurring solutions are beginning to emerge for some of the issues in this area, but many interfaces still lack standardization and best practices.

This research represents an initial move towards understanding multilingual software users' requirements in a world of rapid social and technological change. Putting multilingualism as a focus of interaction design can improve the usability, accessibility, and sustainability of software. According to Romaine, although monolinguals are a minority when considering the world as a whole, they are a very powerful minority, often imposing their language on others, who have no choice but to become bilingual [Romaine, 1989]. As such, designing for multilingualism also means designing for marginalized populations that have had their experience impaired for a long time or have been altogether excluded from access to technology due to language-related issues.

As the research was focused on academic communities, future studies that include technology users with different social backgrounds are recommended. In particular, it would be interesting to include participants from minority or underrepresented groups, such as Romansh-speaking communities (in Switzerland), indigenous peoples (in Brazil), and immigrants/refugees (in both countries). Interviews are seen as a good complement to questionnaires and help clarify relevant issues. Studies on established and innovative design solutions aimed at multilingualism are also welcome with the potential to inform professionals in the field and instigate research towards a more inclusive HCI design.

8.2 Limitations of the study

This section discusses the limitations of the studies and possible actions to mitigate them. The main limitations relate to non-probability sampling, selection biases, and the small number of participants (in the evaluation studies).

Regarding the online survey, the adopted nonprobability sampling prevented us from generalizing the findings. However, large samples were obtained in both countries, ensuring that the study was still relevant. The fact that the study focused on academic communities may also impact the results. Due to the demands of the universities studied, undergraduate and graduate students are expected to have greater familiarity with languages and technology. A more in-depth assessment of the impact of these participant characteristics would require a comparison with other populations. The analyses conducted in this study sought to consider this specific sample characteristic, and it is recommended that future studies take the same precautions. Nevertheless, comparisons between the results from these two culturally and linguistically different environments still allowed us to gain valuable insights. A phase of interviews with survey participants from both institutions has already been approved by the ethics committees and is envisioned for the near future, allowing us to deepen the issues raised by the first study.

Selection bias is a limitation of the exploratory research of websites and applications that was the basis for the patterns discovery. The choice of the systems used to develop the pattern language could influence the patterns to be found and how they would be described. To mitigate this limitation, we combined systems arbitrarily chosen through exploratory research with systems mentioned in online rankings. Nonetheless, the fact that most of the systems were websites with participatory web characteristics remains a limitation. To overcome this limitation, we suggest a new round of pattern discovery that includes more mobile and desktop applications.

The main limitation of the validation studies is the limited number of participants and the possible bias in their selection. To overcome this limitation, conducting multiple runs of the focus group inviting different participants is recommended and planned as a future work. In future editions of the design workshop, variations in the dynamics of the activity are recommended to try to increase participant engagement. Some planned changes for the workshop include increasing activity time, reducing the number of participants per workshop, and providing more active moderation.

8.3 Ethical considerations

The project documentation, including the project description, informed consent forms, and questionnaires, was submitted to the research ethics committees of USI and PUCRS and analyzed between March and July 2023. At USI, the application was submitted on 28 March 2023 and the approval was issued as Decision CE 2023-6 issued on 26 April 2023. At PUCRS, the project was registered in *Plataforma Brasil*, the national Brazilian system, as CAAE 65338122.9.0000.5336 (amendment E1) and approved on 01 July 2023.

Declarations

Authors' Contributions

DMR contributed to the conception, investigation, and writing of this study—original draft. LSG contributed to the investigation, and writing—review & editing. ML contributed to methodology, supervision, and writing—review & editing. MS contributed to conception, methodology, supervision, and writing—review & editing.

Competing interests

The authors declare that they have no competing interests.

Acknowledgements

The authors thank USI and PUCRS for supporting this research. We also thank the members of the academic communities who responded to the questionnaire and helped advance science.

Funding

This research was funded by the Federal Institute of Rio Grande do Sul (IFRS) through the grant of a paid leave during the study period. The grant was regulated by the *Edital No. 015/2021 (IFRS - Campus Restinga)* and by the Brazilian federal Law No. 8.112 of 11 December 1990. Leandro acknowledges the Federal Institute of Mato Grosso do Sul (IFMS), USI, and the Swiss National Science Foundation (SNSF) for supporting this research.

This research was also funded, in the form of a partial scholarship, by the Brazilian Ministry of Science, Technology and Innovations, with resources from Law No. 8.248, of October 23, 1991, within the scope of PPI-SOFTEX, coordinated by Softex in cooperation with PUCRS and published as *Residência em TIC 02 - Aditivo, DOU 01245.012095/2020-56*.

Finally, the main author acknowledges the Brazilian Coordination for the Improvement of Higher Education Personnel Foundation (CAPES) for the grant of a scholarship during a six-month period of studies in Switzerland, awarded under *Projeto Institucional de Internacionalização* (PII), *Programa CAPES-PrInt*, under the terms of Edital CAPES 041/2017 and Edital PUCRS-PrInt 05/2022 *Bolsa de Doutorado Sanduíche no Exterior*.

Availability of data and materials

The datasets resulting from the survey cannot be disclosed due to agreements with the institutions. Other data generated and/or analyzed during the current study will be made available upon request.

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Appendix 1

Table 6. Selected systems for patterns discovery.

Platform[27]	**Seg.**[28]	**Name**	**Version / Address**[29]	**Source**[30]
Desktop	Prod	LibreOffice	7.6.2.1 (for Mac)	Exp
Desktop	Prod	Microsoft Word for Mac	15.56	Exp
Desktop	Prod	Microsoft Word for Windows	365	Exp
Desktop	Prod	Pages	12.1	Exp
Desktop	Browser	Firefox	v112.0.2 (for Mac)	SC;Sim
Desktop	Browser	Google Chrome	v.112.0.5615 (for Mac)	SC;Sim
Desktop	Browser	Microsoft Edge	119.0.2151.44	SC;Sim
Desktop	Browser	Safari for Mac	v16.4.1	SC;Sim
Input	MKeyb	ASHATA Arabic Keyboard	Arabic/English	Exp
Input	MKeyb	Dianma USB Keyboard	Russian/English	Exp
Input	MKeyb	Erika Model 5 Bilingual	Bulgarian/English	Exp
Input	MKeyb	YUNZII X75 Wired-Korean	Korean/English	Exp
Mobile	Ebook	Amazon Kindle for Android	14 (Apr 2023)	Exp
Mobile	Ebook	Play Books for Android	30 (Apr 2023)	Exp
Mobile	Dict	Wikipedia for Android	13 (Apr 2023)	Exp
Mobile	VKeyb	Gboard	13.5.04.566637127	Exp
Mobile	VKeyb	Microsoft SwiftKey	9.10.23.20	Exp
Mobile	VKeyb	Samsung Keyboard	5.6.10.31	Exp
OS	DeskOS	macOS Monterey	12.6.2008	SC;Stat
OS	DeskOS	Ubuntu	20.04.1 LTS	SC;Stat
OS	DeskOS	Windows	10 21H1	SC;Stat
OS	MobiOS	Android	13	SC;Stat
OS	MobiOS	iOS	15.1	SC;Stat
Web	Hotels	Hostelworld	`hostelworld.com`	Exp
Web	Hotels	Agoda	`agoda.com`	Sim
Web	Hotels	Airbnb	`airbnb.com`	Sim
Web	Hotels	Booking.com	`booking.com`	Sim
Web	Hotels	Expedia	`expedia.com`	Sim
Web	Hotels	Marriott	`marriott.com`	Sim
Web	Account	Deloitte	`deloitte.com`	WGR
Web	Account	KPMG	`kpmg.com`	WGR
Web	AirTravel	American	`aa.com`	Sim
Web	AirTravel	Delta	`delta.com`	Sim
Web	AirTravel	Ryanair	`ryanair.com`	Sim
Web	AirTravel	Southwest	`southwest.com`	Sim
Web	AirTravel	United	`united.com`	Sim
Web	Beauty	NIVEA	`nivea.com`	WGR
Web	Books	Kindle Cloud Reader	`read.amazon.com`	Exp
Web	Books	Play Books	`play.google.com/books`	Exp
Web	Books	Archive of Our Own	`archiveofourown.org`	Sim
Web	Books	Author.Today	`author.today`	Sim
Web	Books	Ficbook.net	`ficbook.net`	Sim
Web	Books	Litnet	`litnet.com`	Sim
Web	Books	Wattpad	`wattpad.com`	Sim
Web	Hardw	Intel	`intel.com`	WGR
Web	Tech	Adobe	`adobe.com`	WGR
Web	Conglo	3M	`3m.com`	WGR
Web	Electro	Apple	`apple.com`	WGR

[27] Desktop = Desktop Application; Input = Input Device; Mobile = Mobile App; OS = Operating System; Web = Website / Web app.

[28] Hotels = Accommodation and Hotels; Account = Accounting and Auditing; AirTravel = Air Travel; Beauty = Beauty and Cosmetics; Books = Books and Literature; Ebook = Books and Literature - Ebook; Hardw = Computer Hardware; Tech = Computers Electronics and Technology; Conglo = Conglomerate; Electro = Consumer Electronics; Cook = Cooking and Recipes; DeskOS = Desktop and Notebook OS; Dict = Dictionaries and Encyclopedias; Food = Food and Drink; Furn = Furniture; Transp = Ground Transportation; Cars = Makes and Models; Markt = Marketplace; MKeyb = Mechanical Keyboard; MobOS = Mobile OS; Photo = Photography; Prod = Productivity; SwDev = Programming and Developer Software; Romance = Romance and Relationships; Search = Search Engines; ShipLog = Shipping and Logistics; Social = Social Networks and Online Communities; Attract = Tourist Attractions; Travel = Travel and Tourism; TvStream = TV Movies and Streaming; VKeyb = Virtual Keyboard; Browser = Web Browser.

[29] All websites accessed in October 2023

[30] Exp = Exploratory research; Sim = SimilarWeb Oct 2023; SC = StatCounter Oct 2023; Stat = Statista Jul 2023; WGR = Web Globalization Report 2023

Web	Electro	Philips	philips.com	WGR
Web	Cook	Allrecipes	allrecipes.com	Sim
Web	Cook	Cookpad	cookpad.com	Sim
Web	Cook	Food Network	foodnetwork.com	Sim
Web	Cook	Giallo Zafferano	giallozafferano.it	Sim
Web	Cook	Kurashiru	kurashiru.com	Sim
Web	Dict	Google Translate	translate.google.com	Exp
Web	Dict	Microsoft Translator	translator.microsoft.com	Exp
Web	Dict	DeepL	deepl.com	Sim
Web	Dict	Eksi Sözlük	eksisozluk1923.com	Sim
Web	Dict	Quora	quora.com	Sim
Web	Dict	ScienceDirect	sciencedirect.com	Sim
Web	Dict	Wikipedia	wikipedia.org	Sim
Web	Food	Nestlé	nestle.com	WGR
Web	Furn	IKEA	ikea.com	WGR
Web	Transp	Uber	uber.com	WGR
Web	Cars	Ford	ford.com	WGR
Web	Cars	Volvo Cars	volvocars.com	WGR
Web	Markt	AliExpress	aliexpress.com	Exp
Web	Markt	Decathlon (Brazil)	decathlon.com.br	Exp
Web	Markt	Decathlon (Switzerland)	decathlon.ch	Exp
Web	Markt	Shein	shein.com	Exp
Web	Markt	Amazon	amazon.com	Sim
Web	Markt	Amazon (Japan)	amazon.co.jp	Sim
Web	Markt	eBay	ebay.com	Sim
Web	Markt	Etsy	etsy.com	Sim
Web	Markt	Rakuten	rakuten.co.jp	Sim
Web	Music	Spotify	spotify.com	WGR
Web	Photo	Canon	canon.com	WGR
Web	Photo	Nikon	nikon.com	WGR
Web	Prod	Google Accounts	myaccount.google.com	Exp
Web	Prod	Google Docs	docs.google.com	Exp
Web	SwDev	Microsoft	microsoft.com	WGR
Web	Romance	Tinder	tinder.com	WGR
Web	Search	Baidu	baidu.com	Sim
Web	Search	Bing	bing.com	Sim
Web	Search	DuckDuckGo	duckduckgo.com	Sim
Web	Search	Google Search	google.com	Sim
Web	Search	Yandex	yandex.ru	Sim
Web	ShipLog	DHL	dhl.com	WGR
Web	Social	Reddit	reddit.com	Exp
Web	Social	Facebook	facebook.com	Sim
Web	Social	Instagram	instagram.com	Sim
Web	Social	TikTok	tiktok.com	Sim
Web	Social	WhatsApp	whatsapp.com	Sim
Web	Social	X (ex-Twitter)	twitter.com	Sim
Web	Tour	GetYourGuide	getyourguide.com	Sim
Web	Tour	KKday	kkday.com	Sim
Web	Tour	Klook	klook.com	Sim
Web	Tour	Universal Studios (Japan)	usj.co.jp	Sim
Web	Tour	Viator	viator.com	Sim
Web	Travel	Tripadvisor	tripadvisor.com	Exp
Web	TvStream	IMDB	imdb.com	Sim
Web	TvStream	Max	max.com	Sim
Web	TvStream	Migu Video	miguvideo.com	Sim
Web	TvStream	Netflix	netflix.com	Sim
Web	TvStream	YouTube	youtube.com	Sim

Appendix 2

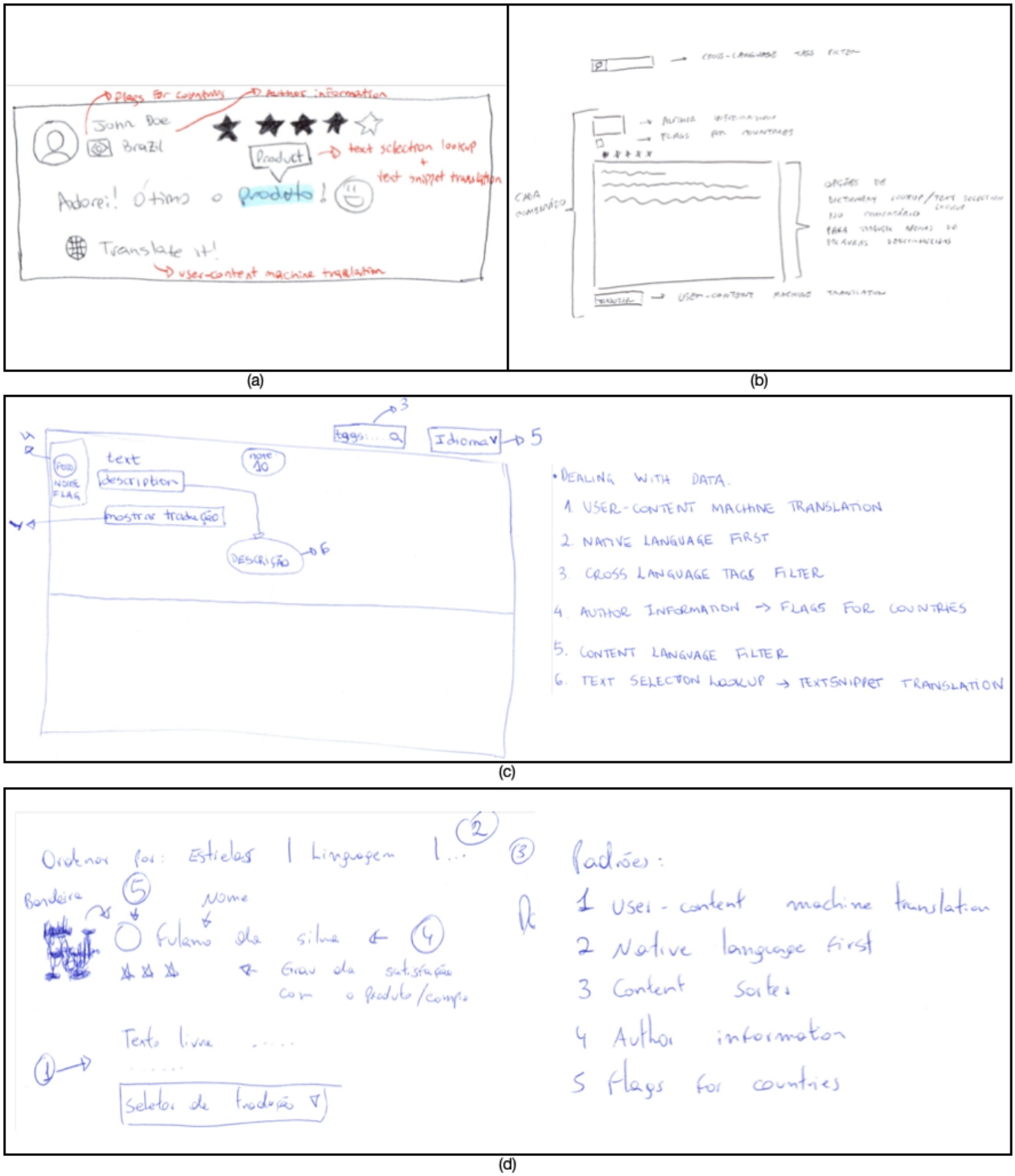
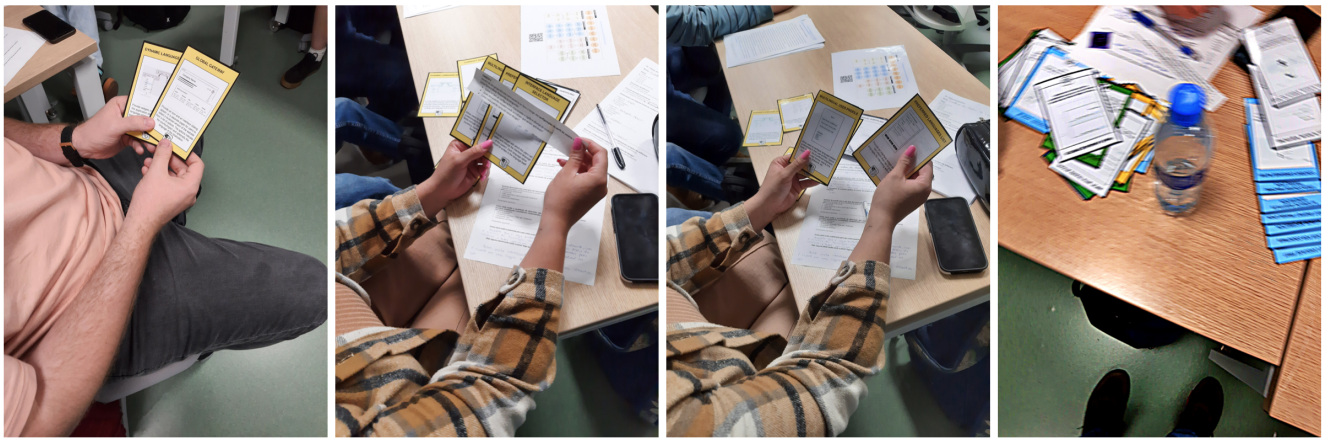


Figure 17. Sketches made by focus group participants: PFG1 (a), PFG3 (b), PFG2 (c), and PFG4 (d). The text within the sketches mixes English and Portuguese.



(a) (b) (c) (d)

Figure 18. Participants of the design workshop present their solutions using the pattern cards distributed to them.