# Deriving socio-technical good practices for automatic sign language processing systems from socially aware codesign

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**Abstract**

In this paper, we report on the discovery process that resulted from a series of semio-participatory workshops with Deaf community codesigners. This process was part of the user research conducted to substantiate the design of solutions to support autonomy in communication and information access for deaf persons who are sign language users. In our user research, we carried out four semio-participatory workshops, as defined by the socially aware design approach. We invited members of a Sign Language community into a democratic design process, providing interested parties with opportunities to reflect on experiences and preferences in the context of automatic sign language processing (ASLP) systems. Our main contribution is the formulation of 63 socio-technical good practices for the design of ASLP systems organized at the social, pragmatic, semantic and syntactic levels for both their human and technological aspects. Two other contributions resulted from our literature review and workshop planning: Firstly, we formalized the steps necessary to engage with a deaf community in the codesign process. Secondly, we present an analysis of our research through the lenses of five calls to action: including Sign Language community members as codesigners, discussing real-world applications, broadening the concept of user interface guidelines to socio-technical good practices, identifying the challenges to find representative datasets, and discussing issues involved in standardized annotated videos in sign language. We thus present both empirical and methodological contributions to the field of Human-Computer Interaction.

**Keywords**

Sign language, Codesign, Good practices, Socially Aware Design, Automatic processing.

## 1. Introduction

In this paper we present procedures and outcomes from conducting four workshops, following the Socially Aware Design approach [1]. By using this approach, we aimed to build automatic sign language processing (ASLP) systems that are soundly based on user studies. As proposed by [2], ASLP include three types of research categories: recognition, generation and translation. In brief, automatic sign language recognition (ASLR) refers to systems which capture static or dynamic images and movements of sign language communication as input and deliver speech or text in a written/oral language as output. Automatic sign language generation (ASLG) refers to systems which capture speech or text of a written/oral language as input and deliver animated avatar communicating in sign language as output. Automatic sign language translation (ASLT) may refer to systems which perform one or two-way translation between a sign language and a written/oral language, possibly using ASLR or ASLG as part of its process.

Our recent work [3], [4], [5]] has revealed a gap in that only few research projects that aim to build ASLP systems are soundly based on user studies. We posit that ASLP system design should engage all

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interested parties as part of the research team, in a collaborative perspective towards a universal design, including Sign Language Community members and hearing persons with diverse backgrounds. In this paper, we use the term Deaf Community or Sign Language Community to refer to a subpopulation among the diverse and larger group of people who are D/deaf [6] and who are sign language users.

With this human-centered approach as our research core, we have been conducting work on the design of technology for, with and by a Deaf Community that builds upon the notions of Socially Aware Design. Baranauskas [1] structured Socially Aware Design over the informal, formal and technical levels of Hall's culture theory [7]. From this viewpoint, the design of a technical system takes into consideration the lenses of the informal and formal levels of a given social group. By doing so, researchers take into account the point of view from different stakeholders, paying attention to aspects such as culture, values, behavior patterns and preferences from the informal perspective, and laws, regulations, rules and policies from the formal perspective. These three perspectives situate the design of interactive systems in a socioeconomic and cultural reality, which includes a diverse set of interested parties as codesigners, leading to the construction of products based upon collaborative meanings. This situated design process is organized into semio-participatory workshops, in which a set of artifacts (informal, formal and technical) are used in inclusive participatory practices to mediate communication and to register the entire codesign process.

Our work with a Deaf Community has progressed through several stages, focusing mainly on the design of ASLP systems. As a starting point for the codesign of such interactive systems, we conducted a systematic literature review of user studies for the design of ASLP systems [8]. In that work, we analyzed four major aspects of primary studies: goals and research methods, user involvement and design life cycle, cultural and collaborative aspects, and lessons learned from empirical works, focusing on the human and the context components of a product design. Our notion of ASLP systems was inspired in [2], which encompasses any automatic system to generate and to recognize sign language, as well as to translate to and from sign language.

In this paper, we share our understanding of socio-technical aspects that are involved in the design of ASLP systems with a Deaf community as codesigners. In order to uncover evidence on socio-technical aspects, we relied on the guidance of the socially aware design approach by conducting four semio-participatory workshops with Deaf community codesigners. This discovery process required paying attention to details of what the codesign sessions with deaf signers revealed to us. Our main contribution is the formulation of socio-technical good practices for the design of ASLP systems. Additionally, we present two other contributions that resulted from conducting our literature review and planning each workshop, as we realized they could help other researchers who carry out similar work (e.g., with deaf communities or in the design and development of ASLP systems). The first contribution is an analysis of various aspects of our research through the lenses of the five calls to action proposed by [2], a research group that has been using an interdisciplinary approach to the design of ASLP systems. The second contribution is a formalization of the steps we followed to engage with a deaf community in the codesign process. We thus present both empirical and methodological contributions [10] to the field of Human-Computer Interaction (HCI).

## 2. The Socially Aware Design Approach

Socially Aware Design is a human-computer interaction approach, proposed by Baranauskas [1], grounded in the theories and concepts of culture studies, participatory design [12], organizational semiotics [13] and principles of the design for all [14]. In this section, we provide background on the approach and its concrete artifacts as well as pointers to salient related work that has explored its use.

The semio-participatory framework, a representation that is helpful in explaining Socially Aware Design, considers society, or a sample of it, as a wrapper for three levels of culture study, as layers of a semiotic onion [15], converging from the informal and formal levels to the technical level. This means that in order to design a product at the technical level, we need to consider culture, beliefs, and everyday life (from the informal level) as well as learned procedures (from the formal level) of the interested parties. This implies that above human-centered design we should consider context-centered or society-centered design. Taking these principles into account, semio-participatory workshops, using inclusive

participatory practices, are conducted to make sense of communication between interested parties among those levels.

Inclusive participatory practices involve participatory sessions with interested parties, providing communication support, a physically accessible environment, and easy-to-use artifacts. Three concrete artifacts were used during the semio-participatory workshops in this research: the Stakeholders Identification Diagram, the Evaluation Frame and the Semiotic Framework [16]. In addition to the Socially Aware Design recommended artifacts, we designed a Rating Scenarios artifact, and used it in Semio-Participatory Workshop 2. This artifact presents ideas for scenarios inspired by related work [[18], [19], [20], [21], [22].

The Stakeholders Identification Diagram artifact, used in Semio-Participatory Workshop 1, is a graphical representation consisting of five concentric circles: Starting from the center, a circle represents Operation (intended solution), followed by Contribution (main actors and responsible parties), Source (clients and suppliers), Market (partners and competitors) and Community (bystanders and legislators). This means that stakeholders who are closer to the *Operation* are those who can collaborate the most with the project. This artifact helps participants in identifying interested parties, from the four above mentioned categories, who they believe would be key to participate in the codesign process.

The Evaluation Frame artifact, used in Semio-Participatory Workshops 3 and 4, supports brainstorming sessions, where codesigners socialize questions and problems, as well as ideas and solutions for the technology's design, taking into account each actor in the Stakeholders Identification Diagram artifact. For this research, we proposed an adaptation of the Evaluation Frame artifact, which presents each identified stakeholder as well as a standard representation for questions and problems, and ideas and solutions. Each element includes short and simplified texts side by side with a representative image in a separate sheet shown one at a time for reducing memory overload.

The Semiotic Framework (or Semiotic Ladder) [[16], [17]–used after conducting the four Semio-Participatory Workshops–is an artifact used to organize and to make sense of the ideas collected. The Semiotic Ladder artifact supports these activities by organizing *socio-technical good practices*–considering a society-centered design–into six levels: social, pragmatic, semantic, syntactic, empirical, and physical levels, from top to bottom in the ladder. The social level refers to the effects of system use, such as expectations and culture. The pragmatic level refers to the system's utility, such as intentionality of a semiotic sign and communication. The semantic level refers to the meanings of the interface elements, such as representative labels and icons. The syntactic level refers to the system's structure, such as the navigational model and standards. The empirical level refers to communication channels using the infrastructure, such as databases and internet connection. The physical level refers to the system's infrastructure, such as memory, processing capacity and devices.

A significant number of related works that have applied concepts and artifacts of Socially Aware Design and conducted semio-participatory workshops have been reported in the literature. Some have studied meta-communication in inclusive scenarios [23] or proposed to extend the approach to include cultural and value perspectives to the design of interactive systems [24], whereas other have presented frameworks for assistive technology design [[25], [26], [27], [28]].

## 3. Research on automatic sign language processing (ASLP) systems in Mexico

Since we conducted the field research in Mexico, we felt motivated to learn about characteristics of local research on ASLP systems and types of user studies related to this topic. We were interested to know whether there were research groups working on this topic, to understand research characteristics and to confirm whether investigation has been conducted on user studies on this domain.

In this exploratory study, using Google Scholar we found 43 works (14 in Spanish and 29 in English) with publication years between 2002 and 2019. Nineteen works were published in 2016 and 2017, the period of most interest in this topic in the country.

The works we found were conducted in 25 institutions from eleven states and Mexico City (*Ciudad de México*, CDMX). Some were carried out in collaboration with institutions from different states or countries (such as the United States and Italy). Five states stand out with higher numbers of scientific production on ASLP systems: CDMX (15), State of Mexico (6), Oaxaca (6), Puebla (6), and Veracruz

(6), whereas five institutions lead this production: Instituto Politécnico Nacional (IPN, 11), Universidad Autónoma del Estado de México (UAEM, 8), Universidad Tecnológica de la Mixteca (UTM, 6), Benemérita Universidad Autónoma de Puebla (BUAP, 4) and Universidad Veracruzana (UV, 4).

Twenty-four papers come from eight research groups in six institutions, reporting advances of their work. Six papers from UTM in Oaxaca, eight papers from three different groups of IPN in CDMX, five papers from two groups of UAEM in México state (Teotihuacan Valley and Texcoco, respectively), two papers from Universidad Tecnológica de Puebla (UTP) and BUAP, and three works from UV. Based on the number of dedication years and number of publications, we can infer that studies on ASLP systems in Mexico are stronger in these groups. Nineteen are isolated works from different research groups with only one publication each.

Among the 43 works we found, thirty-seven reported research conducted on Mexican Sign Language (LSM, *Lengua de Señas Mexicana*), three on American Sign Language (ASL) and three did not specify a sign language. Regarding the research focus within sign language processing studies, fifteen worked merely on letters of the alphabet [[29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], six on letters and words [[18], [43], [44], [45], [46], [47]], four only on words [[48], [49], [50], [51]], four on sentences [[52], [53], [54], [55]], three on numbers and letters of the alphabet [[56], [57], [58]], two on numbers, letters and words [[59], [60]], two on words and sentences [[61], [62]], one on hand configuration and numbers [45], one on phonetic units [63], one on vowels [64] and four did not mention their focus [[65], [66], [67], [68]].

Considering that research on automatic sign language processing systems encompasses various topics studied by many researchers around the world, we identified twenty-six works on ASLR systems, thirteen on ASLT systems, two on ASLG associated with ASLR systems, one on a dictionary and one on a database challenge contest. Amongst the ASLT systems group of papers, there are many with ASLR systems characteristics. Therefore, there is a tendency in research on recognition of letters of the alphabet, numbers, and isolated signs. This may "risk misrepresenting sign language recognition as a gesture recognition problem, ignoring the complexity of sign languages as well as the broader social context within which such systems must function" [2]. Six works present further advances by conducting studies of sentence processing and one on phonetic units, which are approaches that show a broader understanding of the complexity of sign language communication.

With respect to potential users' involvement, in the related work (Section 3), thirty works reported some type of participation and thirteen did not mention anything about it. From works that mentioned user involvement, twenty-one noted that individuals participated in the process to compose the authors' database, thirteen in tests of the proposed system, two in planning of the database, one in the needs, activities and context identification phase, and one in the opinion collection about the prototype design. Six works (20%) explicitly reported involvement of deaf persons as participants [[29], [33], [39], [52], [54], [60]]. Only one work (3,34%) has emphasis on the HCI field of research [33], where the author conducted the four phases of the HCI life cycle [69] including potential users as participants. Moreover, among these 20% works that are related to user studies, none neither investigated about context or society-centered design nor proposed socio-technical good practices for the design of ASLP systems.

## 4. Research methodology outline

In a previous study [6], we conducted interviews with members of the Sign Language community in order to understand demographics data and socioeconomics and cultural aspects, and to invite them to participate in the planned Semio-participatory Workshops. By member of the Sign Language community, we refer to D/deaf persons, teachers and family members of D/deaf persons and interpreters who may be D/deaf or hearing persons, but in either case are sign language users. Out of 11 interviewed participants, 7 accepted the invitation to continue collaborating and signed an informed consent; however, only 5 of them actually participated as codesigners. It is worth noting that ASLP systems are intended to provide communication between D/deaf signers and hearing non-signers. For that matter, we consider it important to have representatives of both categories of stakeholders in participating as codesigners of such solution. Our goal as a research team is to gather a diverse group of collaborators; This, however, does not impose a minimum number for each type of stakeholder in the team.

We conducted four Semio-participatory Workshops, which took place in a classroom at the local Association of the Deaf, as one-hour sessions every two weeks. The researchers (R1 and R2) were familiar with the Sign Language community since they were taking LSM lessons at the Association; however, they were not yet proficient enough to fully communicate with participants in LSM. Therefore, in all sessions we had support of a LSM interpreter, who also participated as codesigner. This interpreter helped recruit other members of the Sign Language community. The informed consent was one of the documents analyzed and approved, along the research project, by the university ethics committee for investigations conducted with human beings.

In the inclusive participatory practices, we used four types of artifacts. For the workshops, artifacts were printed, and participants could use colored markers, post-it notes, and stickers. Following the Socially Aware Design approach, the three artifacts we used are: the Stakeholders Identification Diagram, the Rating Scenarios, the Evaluation Frame, and the Semiotic Ladder. We filmed and transcribed the inclusive participatory practices.

## 5. The Semio-Participatory Workshops

In this section, we present participants and procedures, as well as outcomes from the four semio-participatory workshops carried out biweekly for two months. Subsection 5.3 covers descriptions of two workshops since we ran them back-to-back using the same artifact.

### 5.1. Workshop 1: Stakeholders Identification Diagram

Semio-participatory Workshop 1 was conducted with five codesigners, in which participants from the Sign Language Community included two D/deaf persons, a mother of a D/deaf person, a LSM Interpreter and a Researcher. Three codesigners were women and two men, with age average of 38.6, ranging from 19 to 52 years old.

In our case of interest, the alternative solution is related to automatic sign language processing (ASLP) systems for sign language recognition, generation and translation. As the main activity of the Semio-participatory Workshop, we conducted the inclusive participatory practice using the original Stakeholders Identification Diagram artifact translated into Spanish and including ASLP systems as the Operation. In Operation (intended solution) is placed at the innermost and core circle of the stakeholders' layers in the artifact, which range from the most (closest) to the least (farthest from the center) interested parties.

The task of the codesigners –members of the Sign Language community and researchers as a team— in this session was to identify the potential stakeholders. From the closest interested parties, in the Contribution category referring to main actors and responsible parties, through the Source category referring to clients and suppliers and the Market category referring to partners and competitors, to the Community category referring to bystanders and legislators.

As a deliverable of Semio-participatory Workshop 1, we produced a list of identified stakeholders for each category who codesigners inferred could collaborate in the Socially Aware Design process of ASLP systems. The four categories of the Stakeholders Identification Diagram artifact were elicited as follows: (a) Contribution, with nine stakeholders; (b) Source, with five stakeholders; (c) Market, with four stakeholders; and (d) Community, with two stakeholders.

In total, participants identified twenty categories of representatives as relevant stakeholders to take part as codesigners in the proposal of ASLP systems. Our participants belonged to four of those participant categories and make up a sufficiently diverse mix for a first iteration of codesign.

### 5.2. Workshop 2: Rating Scenarios

Semio-participatory Workshop 2 was conducted two weeks after the first one. Out of seven codesigners, four participants were from the Sign Language Community–two deaf teachers, a mother, and a teacher of D/deaf persons–, a LSM Interpreter and two Researchers. Four codesigners were women and three men, with age average of 40.85, ranging from 20 to 57 years old.

In the first Semio-participatory workshop, we noticed a need to explore other possibilities of scenarios in which ASLP systems could be embedded, since at that moment we did not intend to codesign user interfaces. We designed fifteen scenarios (Table 1) in which ASLP systems could support communication and information access, reminding codesigners of the Stakeholders Identification artifact in each scenario.

**Table 1**
The fifteen ASLP systems used in the Rating Scenarios artifact.

| # | Scenario | # | Scenario |
|---|---|---|---|
| 1 | Search for words in Spanish using LSM signs in a digital dictionary | 9 | Translation app with armband sensor (LSM to text or speech) |
| 2 | Web search using LSM | 10 | Translation from LSM to text or speech (smartwatch) |
| 3 | Real-time remote communication (signer and non-signer) | 11 | Translation from LSM to text (tablet or smartphone) |
| 4 | Real-time translation from LSM to text or speech, via Smartphone | 12 | Automatic generation from LSM to SignWriting |
| 5 | Real-time translation using selfie-stick | 13 | Automatic evaluation of a video in LSM (for education) |
| 6 | Real-time and in-person communication mediated by a glass interface or a screen (signer and non-signer) | 14 | Communication in LSM with a robot (for information access) |
| 7 | LSM projection on a non-signer's chest | 15 | Translation from text to LSM |
| 8 | Glasses to visualize translation from and to LSM | | |

In Semio-participatory Workshop 2, the Rating Scenarios artifact consisted in a set of previously designed and printed materials, presented in a random order, and numbered at the top left corner. Also, each scenario included a short text explanation next to an illustrative image at the center and, at the bottom, a 5-point Likert scale with smiley faces (ranging from Dislike very much to Like very much), which we called a like-scale. The Rating Scenarios artifact presents what has been proposed in literature for different types of ASLP systems, so as codesigners who were not aware of such systems could get a visual idea of possible related systems.

Displaying on the wall and explaining each scenario at a time, we invited participants to indicate, with a colored dot sticker, how much they liked the design alternative presented as the first task everyone should accomplish. As a second task, after discussing and using the like-scale for each individual scenario, we asked participants to number them from 1 to 15 according to their preferences - 1 being the one they preferred the most, and 15 the least - and discussing their motivations. For this second ranking, participants decided to form two groups, one with two D/deaf members and another with two hearing members. The interpreter decided not to participate in this second ranking task and researchers did not participate in any of the rating tasks.

As a deliverable of Semio-participatory Workshop 2, we generated a spreadsheet, which compiles scenario ratings from Task 1 (like-scale) and Task 2 (ordering). Among the 15 scenarios, six scenarios selected (#1, #2, #3, #6, #11 and #15) were taken for voting in the Workshop 3 to identify the two preferred solutions to design.

## 5.3. Workshops 3 and 4: Evaluation Frame

Workshops 3 and 4 focused on the Evaluation Frame, in which, as prescribed by Socially Aware Design, we brainstormed and ranked questions and problems, and ideas and solutions for each stakeholder type.

Semio-participatory Workshops 3 and 4 were conducted two and four weeks after Workshop 2, respectively. Four codesigners participated in each workshop: two from the Sign Language Community–a deaf teacher and a teacher of D/deaf persons; as well as two D/deaf teachers,

respectively–, a LSM Interpreter, and a Researcher. Three and two codesigners, respectively were women, with age average of 32 and 41 ranging from 20 to 44, and 32 and 52 years old, respectively.

The inclusive participatory practice began with the use of the Evaluation Frame artifact to carry out the brainstorming on questions and problems and ideas and solutions for the design of ASLP systems. Once the two scenarios were selected (#6 and #15), we conducted the session using an adaptation of the Evaluation Frame artifact. The artifact's adaptation consisted of framing an illustrative image for each stakeholder identified in the Semio-participatory Workshop 1 next to its category and identification, and by its side two blank spaces with images and labels representing questions and problems, as well as ideas and solutions.

In Semio-participatory Workshop 3, scenario #15 was ranked as the first preferred scenario, with the argument that it is useful in a broad set of situations, from information access to large contents in written language to data exchange through diverse communication means (e.g., email, instant messaging). The scenario #6 was ranked as the second preferred scenario, for which researchers argued the motives for keeping it, since the main idea is to provide face-to-face bidirectional communication between signers and non-signers.

In order to analyze the Semio-participatory Workshops 3 and 4 data, we organized data collected during Workshop 1. This organization consisted in grouping together some of the potential interested parties into a more general type of stakeholder. Thus, from the original twenty stakeholder's types, we converged into eighteen types. The deliverable of these two Workshops was a table with questions and problems, and ideas and solutions raised by codesigners, whose results we used to plot into the Semiotic Ladder artifact to organize the set of socio-technical good practices we have derived.

## 6. Socio-technical design good practices mapped onto the Semiotic Ladder Artifact

From Section 5 we can observe that the results from applying the artifacts (Stakeholders Identification Diagram, Rating Scenarios and Evaluation Frame) are linked, in the sense that a workshop depends on the results from a previous one. For instance, in Semio-participatory Workshop 1, the stakeholder "School teachers" was elicited as an actor who can contribute in the codesign of ASLP systems. In Semio-participatory Workshop 2, codesigners discussed the possible scenarios in light of the stakeholders elicited, so they were asked questions such as "Can you imagine if this scenario was available for your schoolteacher to work with you as a student? Would this be positive or negative?" to serve as a concrete example to reflect about. In Semio-participatory Workshop 3 and 4, codesigners brainstormed questions and problems, and ideas and solutions related to stakeholders identified in Semio-participatory Workshop 1 and to the two most preferred scenarios. Therefore, codesigners were invited to imagine what kind of questions and problems, and ideas and solutions could arise in a concrete scenario. For instance, a situation where a schoolteacher in a mainstream classroom with many mixed students (signers and non-signers) wants to conduct a pedagogical activity using the scenario #15 as a mediator for communication or collaboration between pairs of students.

As a result, we found a higher number of items on good practices (46) for the "Human information functions" (social, user experience and HCI aspects) than the number of items (17) for the "The IT platform" (technical aspects). Since we were more interested in the human and context aspects for the design of ASLP systems, this list of good practices is a contribution to this line of study that requires an interdisciplinary approach.

From top to bottom of the Semiotic ladder, firstly, we present the three "Human information functions:" Social, Pragmatic and Semantic levels.

1. ***Social level***. Since nowadays still there are many misconceptions about universal sign language (SL), full literacy in written language, communication homogeneity, oralization, among others, the guideline "Educate people about Deaf culture and deaf people's rights" is an important issue to address in many levels of the technologies design. From literature review in this paper and from a previous systematic review, we found that most of the research groups are creating their own sign language database, since there is not a public repository with standardized data for SL of each country. This leads us to the guideline "Have political support to make a distributed

database an official location to share and to receive standardized data (annotated SL videos) as an open science repository to support inter-disciplinary research". One concern of many in the Deaf community is they are contacted by many researchers when they need to substantiate their projects or to fulfil some work agenda. Unfortunately, when projects are "completed" or the workload is finished, they disappear. That is why we included the guideline "Understand who can be potential supporters in the general community to guarantee sustainability of the technologies' adoption and maintenance". Table 2 presents the recommended good practices for the Social level of the Semiotic Ladder Artifact.

**Table 2**
The semio-technical good practices considering the Social level.

| **Social level** |
|---|
| 1. Assign more than one teacher per class or divide the class into smaller groups as a strategy to use the technology |
| 2. (Users) Respect their turn to use the technology and one communicate at a time |
| 3. Respect people's communication choice |
| 4. Involve family in SL learning |
| 5. Face each other, make eye-contact and notice non-verbal cues along with translation |
| 6. Place the interface in a controlled environment to access in a public space |
| 7. Ensure adequate environment for data capture |
| 8. Discuss anonymity and copyrights in the context of sign language translation |
| 9. Ensure technology can provide information ethically to display SL |
| 10. Educate people about Deaf culture and deaf people's rights |
| 11. Have political support to make a distributed database an official location to share and to receive standardized data (annotated SL videos) as an open science repository to support interdisciplinary research |
| 12. Provide detailed information that satisfies actual needs |
| 13. Empower deaf signers by providing them with opportunities to communicate with everyone using SL, without the need of an intermediary |
| 14. Disclose Deaf communities' social activities to invite hearing persons to become familiar with Deaf culture |
| 15. Understand who can be potential supporters in the general community to guarantee sustainability of the technologies' adoption and maintenance |

2. ***Pragmatic level***. The three good practices here meet perspectives of the above three social levels in a more practical way, respectively, "Invite users to switch roles concerning mode of communication", "Populate the database with users' collaboration", and "Record/ register the entire conversation, translations", since they can motivate people to know about Deaf culture, can support the data gathering for a national initiative, and can provide motivation for government or companies to sustain the infrastructure and services for the technology continuance of use. Table 3 presents the recommended good practices for the Pragmatic level of the Semiotic Ladder Artifact.

**Table 3**
The semio-technical good practices considering the Pragmatic level.

| **Pragmatic level** |
|---|
| 1. Support learning |
| 2. Provide training to use technology |
| 3. Know the user through a profile questionnaire |
| 4. Facilitate wayfinding of technology availability |
| 5. Anticipate users' diversity (universal design principles) |
| 6. Allow users to include many signs for different words depending on the state of the country where they live |
| 7. Include/ edit/ exclude dactylology, signs or sentences that came out wrong in SL translation |
| 8. Include/ edit/ exclude words or sentences that came out wrong in the translation of written language |

| Pragmatic level | |
|---|---|
| 9. | Have reviews done by experts, before any content editing or excluding |
| 10. | Decide to delete conversations/ translations once they are concluded |
| 11. | Choose an anonymous mode of interaction. Save data, but not the user's identity |
| 12. | Invite users to switch roles concerning mode of communication |
| 13. | Ensure fluid communication to provide positive perception and emotional reaction |
| 14. | Share translations in social networks or in real-communication apps |
| 15. | Record/ register the entire conversation, translations |
| 16. | Keep a record of the inclusion/ edition/ exclusion made by users |
| 17. | Populate the database with users' collaboration |
| 18. | Disclose promotional materials about Deaf culture |

3. ***Semantic level***. The guideline "Provide textual, audio and video tutorials" is to ensure a broad range of types of users can access and know how to use technologies. In many contexts of use, it is important to keep track of a conversation history, such as medical consultation, academic or lawyer advising; this leads to the guideline "Automatically create a conversation timeline to save translations". The guideline "Recommend usefulness of the result presented by the search or the translation" can support assessment of the technology use for its improvement. Table 4 presents the recommended good practices for the Semantic level of the Semiotic Ladder Artifact.

**Table 4**
The semio-technical good practices considering the Semantic level.

| Semantic level | |
|---|---|
| 1. | Provide textual, audio and video tutorials |
| 2. | Display visual support on the screen in addition to sign language, such as images, maps and videos |
| 3. | Allow search for similar information from previous translations, using text, speech or SL |
| 4. | Recommend usefulness of the result presented by the search or the translation |
| 5. | Consider the state where the user lives in order to access the text translation or the SL communication |
| 6. | Provide representative icons so deaf signers can include/edit/exclude content |
| 7. | Provide a virtual keyboard for whoever wishes to use it |
| 8. | Provide predictive text and autocorrect suggestions for whoever wants to use the virtual keyboard |
| 9. | Provide predictive text and autocorrect suggestion for signs |
| 10. | Automatically create a conversation timeline to save translations |
| 11. | Display translations in a specific portion of the interface and always keep this same layout |
| 12. | Be careful with information occlusion and overcrowded interface |

From top to bottom of the Semiotic ladder, secondly, we present the three "The IT platform": Syntactic, Empirical and Physical levels.

4. ***Syntactic level***. The guideline "Allow users to adjust accessibility settings" can be related to adjustments of color contrast, font size, video/ animation display size, SL to speech for interaction between deaf and blind persons, speed of information presentation, following the adequate standards. Many concerns towards data privacy in specific contexts of use were reported, in spite wanting to keep the record of translations to themselves; the ideal situation is having transparency and well-defined norms to "Provide different privacy protocols for users' data depending on the facilities' nature". Table 5 presents the recommended good practices for the Syntactic level of the Semiotic Ladder Artifact.

**Table 5**
The semio-technical good practices considering the Syntactic level.

| Syntactic level | |
|---|---|
| 1. | Allow users to adjust accessibility settings |
| 2. | Ensure privacy of patients' personal medical records |
| 3. | Provide different privacy protocols for users' data depending on the facilities' nature |

5. ***Empirical level***. The guideline "Self-adapt SL recognition to users with multiple disabilities" regards to specificities of deaf signers who have another disability associated, in order to support positioning in the right place, avoid clicking the wrong icon, recognizing the adequate hand configuration, avoiding feedback that presses the user for quick action, among others. Since the ASLP systems could be embedded in many types of contexts of use, one concern was about the specialized vocabulary used, either to deaf signers who still have to collaboratively create with community new signs as they further achieve higher academic education in diverse areas of knowledge or to guarantee a robust and diverse SL database. For this, the guideline "Gather data from diverse specific' domains" was pro-posed. Table 6 presents the recommended good practices for the Empirical level of the Semiotic Ladder Artifact.

**Table 6**
The semio-technical good practices considering the Empirical level.

| **Empirical level** |
|---|
| 1. Allow a limited number of persons interacting per round of conversation |
| 2. Display real-time translations using 3D animated avatars |
| 3. Self-adapt SL recognition to users with multiple disabilities; |
| 4. Support understanding during a conversation between signers and non-signers |
| 5. Deliver fluid translation, avoiding delays |
| 6. Gather data from diverse specific' domains |
| 7. Ensure good quality internet connection in the environment the technology will be used |
| 8. Define protocol for database storage and access |
| 9. Model and implement a distributed database for a country or a region (group of countries) |

6. ***Physical level***. The guideline "Design one large screen for all, or individual screens for each" attends to expectations for private and public technology use, as well as for individual and collective technology use of a text to SL translator system. As part of the technical planning for supporting both scenarios of technology chosen by participants, the guideline "Determine protocol and infrastructure for information storage" was included. Table 6 presents the recommended good practices for the Physical level of the Semiotic Ladder Artifact.

**Table 6**
The semio-technical good practices considering the Physical level.

| **Physical level** |
|---|
| 1. Design one large screen for all, or individual screens for each |
| 2. Design one large (touch) glass interface or screen for two persons interacting at a time |
| 3. Provide webcam embedded so deaf signers can include/edit/exclude content |
| 4. Download the translations records to a USB memory |
| 5. Determine protocol and infrastructure for information storage |

## 7. Conclusion

The primary goal of this research has been to share our understanding of socio-technical aspects that are involved in the design of ASLP systems with Deaf community members as codesigners. In order to uncover evidence on socio-technical aspects, we relied on the guidance of the socially aware design approach by conducting four semio-participatory workshops with Deaf community codesigners. By presenting how research was conducted, its results and socio-technical good practices we derived, we highlight the importance of considering not only potential users at the center of the design, but also their ecosystem (main actors, responsible parties, clients, suppliers, partners and competitors, bystanders and legislators) and the research impact of this broader view.

Our invitation for a Sign Language community to participate in this democratic design process resulted in an opportunity for all to reflect on and to share social and technical concerns regarding past

experiences and personal preferences in the context of ASLP systems. Participants were more timid in the first workshop, and more participative in the next ones. They understood the potential benefits this type of technology can bring to their lives or to their children or relatives. One deaf participant reported twice she was having fun being a codesigner, she was learning from discussions, and perceiving her ideas were being valued by others and for the project.

We provided a set of sixty-three experience-grounded socio-technical good practices for the design of ASLP systems from which we can follow to the next steps of the research. We recall that the two scenarios chosen by codesigners were #6 (Real-time and in-person communication mediated by a glass interface or a screen (signer and non-signer)) and #15 (Translation from text to SL). These good practices mostly can be applied to both scenarios. However, the social level brings to the table more concerns for Scenario 1, since for many stakeholders' types it involves the conversation between two persons in public environments. Some recurrent codesigner concerns had to do with the use of data from translations versus privacy, educating people about Deaf culture and sign language, and learning how researchers will deal with sign language specificities, such as domain specific language, regionalisms, and providing other visual cues to facilitate understanding and to ensure a positive user experience. These findings and good practices are not set in stone, as we understand the need to complement them with other categories of stakeholders. However, we disclose this contribution to invite whoever seeks to further investigate this subject in an interdisciplinary research team to broaden their views to include the human and context aspects. Also, Artificial Intelligence researchers could benefit from our set of good practices in order to discuss topics related to Fairness, Accountability, Transparency, and Ethics (FATE) since relevant issues still need to be further addressed [11].

Looking back at the entire process, we share a discovery process in light of the Socially Aware Design approach. This discovery process is related to the way inclusive participatory practices can be conducted and artifacts can be adapted to promote participants' engagement in the design of solutions with Deaf community codesigners. We found that an initial stimulus activity related to the topic to be discussed (e.g., presenting a video or an app, making a conversation with questions, inviting for a vote) can be ice-breaking while eliciting data. The core session with an artifact must not take too long. The choice of day and time as well as having a snack help keep energy at a high level. Artifacts that present the same information in different formats (e.g., short, simplified text and image) and are explained in the preferred language of the participants ensure inclusiveness. Sharing the workshop content beforehand with the interpreter can help him or her feel more relaxed and enjoy the activity. Colorful supplies, such as post-its and sharpies, different kinds of stickers (dots, smiley faces, numbers, thumbs up and down) can be seen superfluous, but participants get excited to choose colors and feel motivated to collaborate. Finally, comments and testimonies of participants are valuable, and they should be informed about this by asking them to write down their thoughts on post-its, and to further discuss in their preferred mode of communication.

Additionally, taking the five calls to action proposed by [2], in this research we included Sign Language community as codesigners (Call 1) strengthening bonds with a local association and school, not only conducting the workshops, but also participating in social activities and taking LSM lessons along with them. During semio-participatory workshops, we had the opportunity to discuss real-world applications (Call 2), relating potential stakeholders to potential scenarios of technology use and to problems based on their previous and current life experiences and ideas for solutions. Moreover, we broadened the concept of user interface (UI) guidelines (Call 3) to socio-technical good practices, with results presented in Section 5, in which UI is represented at the semantic level of the semiotic ladder artifact. We identified in literature reviews and in discussions with the Deaf community the difficulty to find public, representative dataset curation (Call 4), especially standardized annotated videos in sign language (Notation standards and support, Call 5). A recurrent topic within the socio-technical good practices was with respect to modeling, building and managing a distributed database. In Mexico, some papers report the use of the video library of the DIELSEME, however, twenty-one papers on ASLP system from Mexico refer to collecting their own dataset.

We had planned at least eight semio-participatory workshops in addition to the four described in this paper. Unfortunately, the COVID-19 pandemic made us rearrange our plans. We were not able to conduct remote workshops, since most participants come from low-income families, and they did not have infrastructure to continue. A remote continuation of the research was possible with Brazilian participants, which currently is an ongoing effort.

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