Implementation of Sound Workspace Awareness to Visually Impaired Users in Synchronous and Cooperative Web Applications

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Abstract: This paper discusses the implementation of accessibility features for visually impaired people in synchronous and cooperative systems on the Internet. Based on the sociocultural scenario of affirmation of difference and on the contexts of cooperation established by Web 2.0, we discuss the application of Sound Workspace Awareness in Groupware tools through Auditory Icons, Earcons, synthesized speech, Live Region, and Screen Readers in a Web chat system. The article presents a qualitative experimental research with internal data validation and an exploratory goal. The process of data collection and analysis was performed using protocols applied with five real users. The results of the experiments showed a satisfactory adherence of these technologies in the construction of Sound Workspace Awareness to screen reader users.

Keywords: Cooperation; Synchronous; Web 2.0; Accessibility; WAI-ARIA; CSCW; Awareness; Auditory Interfaces; blind and visually impaired users.

Implementação de Percepção Sonora no Espaço de Trabalho para Usuários com Deficiência Visual em Aplicativos Web Síncronos e Cooperativos

Resumo: Este artigo discute a implementação de recursos de acessibilidade para deficientes visuais em sistemas síncronos e cooperativos na Internet. Com base no cenário sociocultural de afirmação da diferença e nos contextos de cooperação estabelecidos pela Web 2.0, discutimos a aplicação da Percepção no Espaço de Trabalho em ferramentas do *Groupware* através de Ícones Auditivos, Earcons, fala sintetizada, Live Region e Screen Readers em um sistema de *chat* na web. Trata-se de uma pesquisa experimental qualitativa com validação interna de dados e de objetivo exploratório. O processo de análise de coleta de dados foi realizado utilizando protocolos aplicados com cinco usuários reais. Os resultados das experiências mostraram uma adesão satisfatória dessas tecnologias na construção de percepção sonora para usuários de leitores de tela.

Palavras-chave: Cooperação; Sincronismo; Web 2.0; Acessibilidade; WAI-ARIA; CSCW; Percepção; Interfaces auditivas; usuários cegos e deficientes visuais.

INTRODUCTION

In the Cyber culture context, online interaction and cooperative production have their possibilities enhanced by the assurance of access to technological devices with high degree of interactivity ─ a disposition that is presented on the interface of the second phase of the Web (TIM O'REILLY, 2005). The Web 2.0 widens human interaction spaces, providing a digital space-time that transcends the perspective of a mere aesthetic change.

Having said that, to promote the socialization of ideas and projects, the communication and information resources on the Web have made it easier for people and organizations to meet and to develop ways of interaction that are based on mutual respect and validation of the individualities and differences. As Alain Touraine (2009) affirms, nowadays “we are instructed to recognize the differences and protect the minorities”. However, what minority groups actually seek is the recognition of the human diversity, as individuals with the right to be their own creators, therefore with learning possibilities in different sociocultural spaces.

The Web 2.0 reveals a new paradigm in the design of digital technology interfaces. It is a process that, as Tim O’Reilly (2005) highlights, goes beyond the improvement of the Usability of Web interfaces. It aims at the development of a Participatory Architecture that incorporates technological resources enabling knowledge interconnection and sharing. The development of this Participatory Culture is possible as long as the number of people using its resources increases (TIM O’REILLY, 2005).

In order to establish this Participatory Culture, technological development must be guided by the dialogue among the differences. This modern cultural matrix is acquired when the previous exclusion of any social group and/or the impediment of human rights and duties are effectively confronted. The perspective of socio-digital inclusion demands a change in the technological profile which must have as a goal the overcoming of restrictions in software development designed for one sensory or cognitive specificity. After investigating the interaction of people with diverse needs and computing resources, Castellano and Montoya (CASTELLANO; MONTOYA, 2011) emphasized the need of breaking the logic of software development that is tailored for each impairment. Although computer programs with the label “deficit centered” have the advantage of solving specific sensory or physical problems, they often do not enable social interaction. when developing technologies for people with diverse needs, the rupture with the exclusive design must be assured, as the restrictive design is based on a logic that is centered in the flaws, therefore, it is also centered in social and digital segregation.

This article presents a software model that takes into account the potential of individual and collective authorship involving subjects with and without visual impairment. The investigation was conceptually anchored on the knowledge area established by the study group *Supported Cooperative Work* (CSCW)(PIMENTEL; FUKS, 2011). The aim of this study is to evaluate a set of techniques to create sound awareness and promote accessibility for visually impaired users in synchronous and cooperative interactive tools. Thus, we put together complementary technology such as Auditory Icons, Earcons, synthesized speech, W3C/ARIA Live Region, and Screen Readers to provide sound awareness on a Web chat. Results from an experiment involving five visually impaired users interacting with sighted users are presented here.

CONCEPTUAL BASE OF THE RESEARCH

As an interdisciplinary research area, CSCW investigates how to qualify group work mediated by communication and information technologies (PIMENTEL; FUKS, 2011). The Cyber Culture scene has sponsored researchers in computing so that they stimulate and enable cooperative practices, regardless of geographical distances, allowing people to work together for the achievement of common goals (MOECKEL, 2003).

The cooperation concept has become central within the CSCW framework, and for this reason, it needs to be outlined. Piaget (PIAGET, 1973) has called the attention to the difference between Collaboration and Cooperation. For this cognitivist, Collaboration is characterized as an interaction in which the exchanges of thoughts are performed through communication and coordination of points of view. Cooperation is supported by the concept of Interaction, which occurs through rational operations, and these demand the creation of bonds and affective reciprocity among the subjects going through a learning process. Cooperation happens after Collaboration optimizes and boosts the social exchanges.

The construction of knowledge in cooperative actions occurs by the formation of interaction systems, in which the operatory structure changes the individual and the group as a whole. For the action of cooperation to happen, two concepts must be observed: (1) Interaction, a process structured with mutual respect, reciprocity and autonomy of the participants, (2) Interdependency, resulting from the overlapping relationship between the learner and the object to be known. It stands out that the positivity of the action of these two concepts must create the interaction, in a way that all participants can effectively act and accomplish their goals successfully. Interaction and Positive Interdependency are fundamental factors for the design of cooperative activities.

The success of cooperative tasks is related to the capacity of the participant to be aware of other people's actions so that he/she can be aware of his/her own actions. For Damasio (DAMÁSIO, 2012), the mind is conscious of the world through the brain, and the brain only gathers information through the body. Therefore, the body is the sensory limit which feeds the brain and, later, the mind. In this study, the term awareness is used in the sense of reception, commanded by the sensory mechanism of information input in our body. However, the notion of consciousness is associated to planning, decision making, interaction with the environment, and action choices. For Damasio, consciousness is a feeling with no external senses, since it does not follow any visual, auditory, olfactory or taste pattern. In this paper, we overloaded the term awareness combining it with consciousness.

For the practice of cooperation to occur on Web applications it is fundamental that each participant receives the indication of other participants' actions so that they can establish the context of their own actions, which will make the awareness for cooperation possible. Collaborative and Cooperative people's awareness is influenced by time and space elements that are available on CSCW tools. This concept of awareness was discussed by Antunes et al. (ANTUNES et al., 2014) as Collaboration Awareness. On computing systems, according to what was discussed by these authors, the context of collaboration provides semantics for spaces, characterizing the notion of place. A virtual meeting room, for example, has conventions, roles, and rituals, among other elements that indicate a place. Therefore, the place can combine different information of awareness to attribute a concrete meaning for the users. Consequently, it will be the space in CSCW context that will provide the awareness elements of the tridimensional world and the elements for the interaction management.

Different awareness attributes related to the notion of space can be used in Collaboration Awareness, such as: (1) information on the location and mobility of the users (Location Awareness)(DIX et al., 2000); (2) social privileges, roles, and activities (Social Awareness) (DOURISH, 2006); (3) virtual spaces that define topologies and ways of navigating (Context Awareness) (MACEACHREN, 2005); (4) interaction in a workspace for the performance of a task (Workspace Awareness) (GUTWIN; GREENBERG, 1999); (5) dynamic processes of perception, comprehension of events, and performance of actions (Situation Awareness) (ENDSLEY, 1995).

In order to analyze the cooperative awareness in Sound Chat system this study assessed the interaction of visually impaired users with the system in accordance with Antunes et al. (ANTUNES et al., 2014). Figure 1 shows the notion of Workspace Awareness which, according to Gutwin and Greenberg (1999), is defined as the capacity of recognizing signals to understand the tasks that are being performed at the workplace.

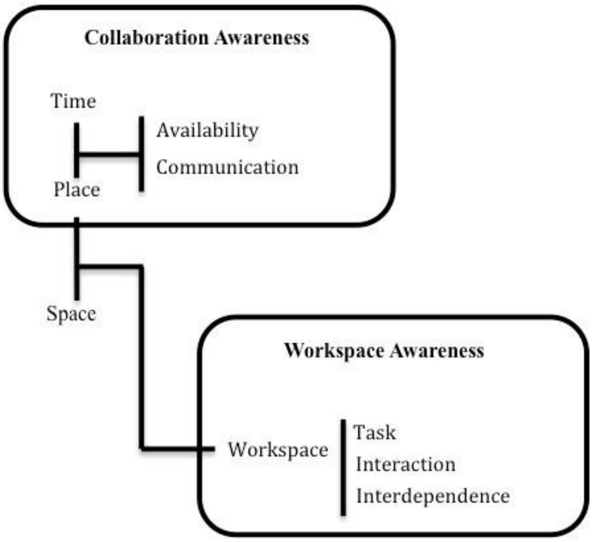

Figure 1 - Workspace Awareness concept - adapted from ANTUNES et al. (2014)

Cooperation Awareness is originated from the perception of the Availability and Communication features of participants in a shared space-time. The Availability, an essential requirement in cooperative systems, makes it possible to identify the status of each participant (online/offline) and also to acknowledge if the users are in different physical spaces. Regarding the Communication features, whether synchronous or asynchronous, users' actions must be announced, connectivity has to be informed, delivery and/or delay of messages must be known.

The Tasks can be perceived through information that allows the identification of who, what, when, and how the set of tasks was proposed to the group as a cooperative action. Another important matter is the Interaction, that is, how the group performs in the Workspace and what information is necessary to support their actions. That way, the feedback is a confirmation resource of the users' actions in the system and the feedthrough shows other users' actions. A notion about Workspace leads to the concept of Interdependence where several types of interdependence can be used in the system, such as support for parallel, coordinate, and mutually adjusted activities. These awareness requirements are elements of considerable importance in cooperative proposals in a Workspace system.

MATERIALS AND METHODS

The subjects' interaction with Sound Chat was analyzed with a qualitative approach in an exploratory context. The investigation on the effectiveness of Sound Workspace Awareness implemented in Sound Chat was structured around five categories previously discussed in Antunes et al. (2014): Availability, Communication, Task, Interaction, and Interdependence. Table 1 explains each of these categories.

Table 1 – Sound Chat Validation Checklist

Categories	**Analysis Questions: the system informs/promotes**
Availability	Were the users available to cooperate (online, offline)?
Communication	When were the messages delivered to the users?
Task	Who was performing a particular task?
	What was the activity [entry, exit, typing, sending and receiving messages] being executed by a user?
	Did the system show the sequence of tasks performed over time?
Interaction	Did the system provide feedback about the user's current actions?
	Did the system notify the user about the other's current actions?
Interdependence	Did the system indicate if users were doing coordinated activities (*e.g.* through a workflow)?
	Did the system indicate if the users were doing parallel activities?

This study comprised a group of five visually impaired users as detailed in Table 2. A research protocol was developed to guide the experiments and establish the observation points to collect users' data interaction. Each experiment lasted approximately 60 minutes.

The sessions were divided into two distinct moments. The first was when the group interacted with each other using the Sound Chat application. The second moment was when each user went through a semi-structured interview to collect more data about the visually impaired experience with Sound Chat. Each experiment group was composed by one visually impaired user and two sighted users. The Sound Chat conversation was informal and its topic was about visually impaired jobs. All users' interactions with the system were saved in a database for further analysis and the experiments were recorded in video and transcribed according to the technique of discursive textual analysis (MORAES, 2003). In this research, all participants signed a term of consent.

Table 2 – Characterization of the research subjects

S1	Blind, 47 years old, majored in Computer Science and Physics, and mastered in Computer Science. More than 10 years of experience with screen readers. Technological configuration: Desktop computer, Windows 10, Jaws 18, and Chrome 60.
S2	Blind, 29 years old, majoring in Management. More than 10 years of experience with screen readers. Technological configuration: Desktop computer, Windows 7, NVDA 2017.2, and Chrome 60.
S3	Blind, 44 years old, acting teacher. More than 10 years of experience with screen readers, but the subject self-declared low experienced with computers. Technological configuration: Desktop computer, Windows 7, Jaws 18, and Chrome 60.
S4	Blind and moderate deafness, 20 years old, majoring in Management. More than 10 years of experience with screen readers. Technological configuration: Desktop computer, Windows 7, NVDA 2017.2, and Firefox 56.
S5	Blind of one eye and low vision of the other eye (limited vision from 1 to 1.5 meters far), 20 years old, majoring in System Analyses. More than 10 years of experience with screen readers. Technological configuration: Desktop computer, Windows 7, NVDA 2017.2, and Chrome 60.

Sound Chat (MACHADO, 2016) is an open source tool to promote the interaction of screen reader users and sighted users in a textual chat on Web supported by sound and visual awareness elements. To provide sound awareness in the system, Sound Chat employs technology such as Auditory Icons and Earcoins, developed with Web Audio API (ADENOT; WILSON, 2015); text-to-speech, implemented through Web Speech API (SHIRES; WENNBORG, 2012); and Live Region develop according to the ARIA recommendation (DIGGS et al., 2016). To encourage the reuse of software, Sound Chat was developed as a Web Component built with the Polymer framework. The system can be used in English, Portuguese, and Spanish, being compatible with desktop and mobile browsers. Figure 2 shows the main interface of Sound Chat.

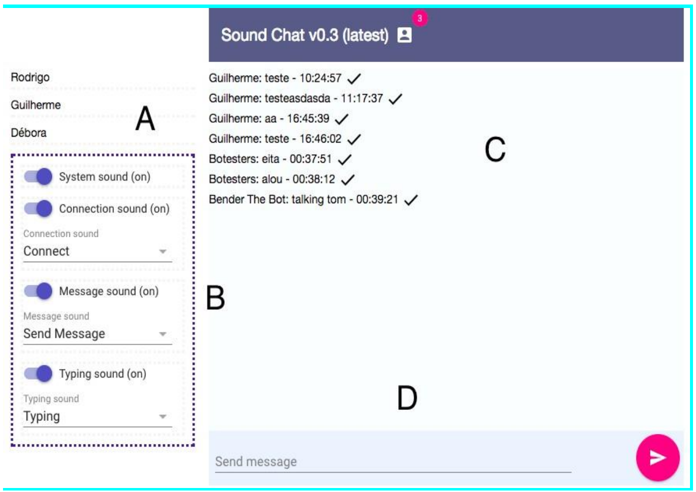

Figure 2 – Sound Chat interface

The Figure 2 presents the main interface of Sound Chat, where it is possible to observe the list of participants (Figure 2 - A), the configuration options (Figure 2 - B), the messages sent (Figure 2 - C), and the area to send messages (Figure 2 - D). By Default, Sound Chat starts with all audio turned on. However, it allows the users to disable or enable all sound features. The system provides specific controls that enable participants to turn the sound off and on or change the sound triggered by four actions: participants logging in/out, sending and receiving messages, and typing. These were based on the Workspace Awareness categories that combined a set of technologies to make visually impaired users notice the actions of the other users through sound (Table 3).

Table 3 – Implementation of Sound Workspace Awareness in Sound Chat

System events	Workspace Awareness Categories Involved	Sound Interface
Connecting	Availability, Task, Interaction (feedthrough)	Abstract sound comparable to a beep (Earcon) + text-to-speech number of connected users + text-to-speech the word "participants" + text-to-speech the name of each connected user (list of names)
Receiving message	Communication (the message inform the delivery time), Task, Interaction (feedthrough)	Abstract sound similar to a pop of a soap ball bursting (Earcon) + text-to-speech the name of the user who sent the message + a Live Region to read the income message
Sending message	Interaction (feedback)	Abstract sound similar to a pop of a soap ball bursting (Earcon)

Typing	Interaction (feedthrough), Interdependence (coordinate)	Concrete sound of keyboard typing (Auditory Icon)

RESULTS AND DISCUSSION

The aim of this study was to evaluate a set of technologies used to implement sound awareness for visually impaired users to interact in equity with sighted users in synchronous and cooperative Web tools. Sound Chat design differs from previous studies in several ways: (1) Verma, Singh and Singh (2013) have not used Screen Readers as the user's agent; (2) Melnyk et al. (2015) have not implemented awareness features in systems, but they have improved the Screen Readers through monitoring features of updates on Web; (3) Thiessen and Hockema (2010) have proposed as a strategy of accessibility through a combination between Live Region and Screen Readers; (4) Sanchez and Baloian (2006) have tested awareness features available upon user's requests.

The results of our experiments showed balance in participation between visually impaired and sighted users. The average of messages exchanged by visually impaired users in our experiment was 38.67% (S1 – 36.17%; S2 – 38.80%; S3 – 38.09%; S4 – 42.35%; S5 – 37.93%). S3 who had never participated of a group interaction in a textual chat application did not have any issues in integrating with others and, therefore, demonstrated acceptable system accessibility and usability. It is worth mentioning that S1, the most experienced user, wrote longer sentences and sent a reduced number of messages.

Regarding the implementation of Sound Workspace Awareness in Sound Chat, in the *Receiving Message* event, written to notify visually impaired users about incoming messages, all subjects of this study declared that this functionality was useful. However, to facilitate navigation, subjects S1 and S2 suggested that messages received should be automatically announced by the system. Although this feature was developed through an Assertive Live Region (*aria-live="assertive"*), the tests showed that only S3 was able to take advantage of the automatic reading message feature. To explain that, we reproduced the behavior of visually impaired users in laboratory and concluded that the Live Region was functional only with JAWS Screen Reader and in a situation where users were not interacting with the keyboard. To understand why only S3 observed the automatic reading message feature, we computed the average number of characters typed per sentence by the users, which were 37.28 (S1 – 61.44; S2 – 60.92; S3 – 13.50; S4 – 32.27; S5 – 21.57). These data showed that S3 was the subject with shorter answers, consequently giving time to announce the received message by the implemented Live Region. Thus, in order to use Live Region, it seems to be necessary to perform several tests to ensure that it will work according to the user's Screen Reader and the Web application in use. This issue also evidenced that it might be difficult to use only Live Region to build a satisfactory Sound Workspace Awareness.

The *Connecting* sound awareness element was designed to identify the availability of the participants who were connected in the system. All subjects were able to perceive the existence of this resource and, consequently, the importance of this sound interface. However, subjects S1 and S2 suggested that the system would announce the list with the names of logged users only at the moment of entry of the visually impaired user into the application, and after that the system would notify the names of people entering or leaving the system. Although the awareness element for the *Connecting* event proved to be useful, S1 and S2 argued that for larger groups this functionality would not be appropriated, since the possibility of this sound resource would cause discomfort or overload. Thus, it was necessary to redesign this feature to properly work with both large and small groups.

The Auditory Icon used to notify the *Typing* event was considered important to synchronize actions among users. At the same way, all visually impaired users considered the Earcon used to represent the *Sending Message* event useful. The results of our experiments indicated that a project of a sound interface seems to be complex enough to justify a complementary use of the technology to create an effective Sound Workspace Awareness for visually impaired users. Thus, we ratified Csapó and Wersényi (2013) when they said that real-world applications should use a conjunction of techniques to build sound interfaces.

In order to identify users that generated events, Sound Chat used text-to-speech through the Web Speech API. Therefore, the browser implemented text-to-speech and reproduced a different voice from the users' Screen Reader. S1, S2, S3, and S5 considered the identification provided by text-to-speech important and did not mention anything about the fact that Sound Chat emitted two different voices. Based on the studies about the Cocktail Party Effect (ARONS, 1992), Thisser and Chen (2007) have suggested that the use of two or more voices could improve the accessibility for visually impaired users. However, we noticed in our experiment that S4, who also had a moderate deafness, considered this possibility annoying and noise polluted. Thus, further investigation is needed to evaluate the possibility to combine two different voices and consider it them an accessibility improvement.

Another aspect observed was related to the implementation of a sequential navigation through the key tab implemented by HTML *tabindex*. S5 complained that the system had no shortcuts to go around Sound Chat areas (Figure 2). Different from Sound Chat, a system to enable cooperation among participants needs more features, for example, a discussion area, a place to work together in an artifact, workflow to coordinate activities, and so on. In other words, a synchronous and cooperative Web application must have more areas to support cooperative activities. For visually impaired users, the system must also implement an easy way to navigate through shortcuts. To conclude, our observation showed that in this type of system enabling a quick navigation among areas is a requirement as important as sound for visually impaired users.

CONCLUSIONS

The Web 2.0 is a strong booster of the Participation Culture, a socio-cultural scene where human action must be woven in the dialogue with the differences. The perspective of socio-digital inclusion demands technological changes that may democratize participation possibilities that emerge from the adoption of asynchronous programming (AJAX) and Rich Internet Applications on the Web. Thus, synchronous and cooperative applications represent a new challenge for the construction of solutions for the web use and access.

This study focused on the analysis of the application of Sound Workspace Awareness in synchronous and cooperative tools through Auditory Icons, Earcons, synthesized speech, Live Region, and Screen Readers. Despite most of awareness categories have been previously tested by visual components, we first concluded that they might be applied as a guide to either create or evaluate sound for Workspace Awareness. In the development process of Sound Chat, we noticed that creating sound awareness is a complex problem to justify the use of a combination of complementary techniques to enable equalitarian interaction among visually impaired and sighted users. Each technology provides possibilities to build sound awareness, for example, Auditory Icons might establish a semantics for an event to help the user's awareness, Earcons might be applied to create alerts for important events, text-to-speech might be used to announce who, how, and when an event was generated, and W3C Live Region, because of its limitations, might be adopted in situations where users interact slowly with the keyboard and with Screen Reader that supports this recommendation. However, we also concluded that it might be difficult to use only one technique or technology to provide effective sound awareness.

In an educational context, a system needs to promote Interaction and Positive Interdependence among the participants to be classified as cooperative. Having said that, it should be taken into account that there are still several complex scenarios to be considered in future investigations. Thus, this research opens to additionally investigate the application of the sound awareness solutions discussed here in educational scenarios such as cooperative writing and cooperative problem solving.

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REFERENCES

ADENOT, P.; WILSON, C. **Web Audio API**. Disponível em: <https://www.w3.org/TR/webaudio/>. Acesso em: 5 abr. 2017.

ANTUNES, P. et al. Reviewing the quality of awareness support in collaborative applications. **Journal of Systems and Software**, v. 89, p. 146–169, 2014.

ARONS, B. A Review of The Cocktail Party Effect. **JOURNAL OF THE AMERICAN VOICE I/O SOCIETY**, v. 12, p. 35–50, 1992.

CASTELLANO, R. E.; MONTOYA, R. S. **Laptop, andamiaje para la Educación Especial: guía práctica, computadoras móviles en el currículoOrganización de las Naciones Unidas para la Educación la Ciencia y la Cultura (UNESCO)**Montevideo, Uruguay, 2011.

CSAPÓ, Á.; WERSÉNYI, G. Overview of auditory representations in human-machine interfaces. **ACM Computing Surveys**, v. 46, n. 2, p. 1–23, 2013.

DAMÁSIO, A. **O Erro de Descartes**. 1. ed. [s.l.] Companhia das Letras, 2012.

DIGGS, J. et al. **Accessible Rich Internet Applications (WAI-ARIA) 1.1**. Disponível em: <http://www.w3.org/TR/wai-aria-1.1/>. Acesso em: 24 abr. 2016.

DIX, A. et al. Exploiting Space and Location as a Design Framework for Interactive Mobile Systems. **ACM Transactions on Computer-Human Interaction**, v. 7, n. 3, p. 285–321, 2000.

DOURISH, P. **Re-space-ing place**. Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work - CSCW '06. **Anais**...New York, New York, USA: ACM Press, 2006Disponível em: <http://portal.acm.org/citation.cfm?id=1180875.1180921&coll=ACM&dl=ACM&CFID=78177206&CFTOKEN=77465977>

ENDSLEY, M. R. Toward a Theory of Situation Awareness in Dynamic Systems. **Human Factors: The Journal of the Human Factors and Ergonomics Society**, v. 37, n. 1, p. 32–64, 1 mar. 1995.

GUTWIN, C.; GREENBERG, S. The effects of workspace awareness support on the usability of real-time distributed groupware. **Interactions**, v. 7, n. 4, p. 9–13, 1999.

MACEACHREN, A. M. Moving Geovisualization toward Support for Group Work. In: **Exploring Geovisualization**. [s.l.] Elsevier, 2005. p. 445–461.

MACHADO, R. P. **Sound Chat: An experimental system for sound awarenes elements validation**. Disponível em: <https://github.com/rodrigoprestesmachado/soundchat>. Acesso em: 9 abr. 2017.

MELNYK, V. et al. Look Ma, No ARIA: Generic Accessible Interfaces for Web Widgets. **Proceedings of the 12th Web for All Conference**, p. 4–7, 2015.

MOECKEL, A. **CSCW: conceitos e aplicações para cooperação**. Curitiba: [s.n.].

MORAES, R. **Uma tempestade de luz: a com-preensão possibilitada pela análise textual discursiva**. Disponível em: <http://www.scielo.br/pdf/ciedu/v9n2/04.pdf>. Acesso em: 24 abr. 2016.

PIAGET, J. **Estudos Sociológicos**. [s.l.] Forense, 1973.

PIMENTEL, M.; FUKS, H. **Sistemas Colaborativos**. [s.l.] Elsevier Inc., 2011.

SANCHEZ, J.; BALOIAN, N. Issues in implementing awareness in collaborative software for blind people. **Computers Helping People With Special Needs, Proceedings**, v. 4061, p. 1318–1325, 2006.

SHIRES, G.; WENNBORG, H. **Web Speech API Specification**. Disponível em: <https://dvcs.w3.org/hg/speech-api/raw-file/tip/speechapi.html>. Acesso em: 5 abr. 2017.

THIESSEN, P.; CHEN, C. Ajax live regions: ReefChat using the fire vox screen reader as a case example. **Proceedings of the 2007 international cross-disciplinary conference on Web accessibility (W4A)**, p. 137, 2007.

THIESSEN, P.; V, B.; HOCKEMA, S. WAI-ARIA Live Regions : eBuddy IM as a Case Example. **W4A2010- Technical Paper, April 26–27, 2010, Raleigh, NC, USA. Co- Located with the 19th International World Wide Web Conference.**, 2010.

TIM O'REILLY. **What Is Web 2.0: Design Patterns and Business Models for the Next Generation of Software**. Disponível em: <http://www.oreilly.com/pub/a/web2/archive/what-is-web-20.html>. Acesso em: 23 abr. 2016.

TOURAINE, A. **Pensar Outramente. O Discurso Interpretativo Dominante**. 1. ed. [s.l.] Vozes, 2009.

VERMA, P.; SINGH, R.; SINGH, A. A framework to integrate speech based interface for blind web users on the websites of public interest. **Human-centric Computing and Information Sciences**, v. 3, n. 1, p. 21, 2013.