

Vocal Village Audioconferencing: A Collaborative SOHO Tool for Teleworkers with Physical Disabilities

Annie Shu Zhen Xu¹, Mark Chignell Ph.D.¹, Koichi Takeuchi², Naotsune Hosono Ph.D.³, Takashi Tsuda⁴

1 University of Toronto, Toronto,, Canada

2 Oki Electric Industry Co., Ltd., Tokyo, Japan

3 Oki Consulting Solutions Co., Ltd., Tokyo, Japan

4 Oki WorkWel Co., Ltd., Tokyo, Japan

ABSTRACT

In this paper we will examine how spatialized audioconferencing can be adapted for use by teleworkers with physical disabilities. We describe a field trial with a Japanese company using the Vocal Village (www.vocalvillage.net) spatialized audioconferencing system, where the voices of individual participants appear as if they are coming from different positions in space, distributed from left to right around the listeners' head. The field trial included a number of activities, such as user profiling, requirements gathering, interface customization, task structuring, and evaluation. A team of seven teleworkers with physical disabilities developed a website during the ten days over which the field trial was run. They provided feedback on their experience in using the Vocal Village both during and after the trial. This paper will discuss how the audioconferencing interface and the Web design task were customized to meet the requirements of the trial participants. Results concerning usability, work satisfaction and related measures will also be resulted, along with suggestions for further initiatives and research in the area of audioconferencing for teleworkers with physical disabilities.

KEYWORDS

User Interface; Audioconferencing; Spatial Audio; Telework; Physical Disabilities

INTRODUCTION

Applications to support telework in Japan for people with disabilities represents a particularly challenging, but important, type of universal design, where information technology needs to be adapted to the needs of a population that is far removed from the able-bodied North American population that has been the focus of much of the prior work on technologies to support telework and online collaboration. In this paper we will examine how spatialized audioconferencing can be adapted for use by teleworkers with physical disabilities.

The paper begins with a review of relevant research literature on telecommuting and disability, with a particular focus on teleworkers in Japan. The Vocal Village audioconferencing system is then introduced, followed by a description of how the trial was carried out and what results were obtained. The results are then discussed in terms of their implications for the design and use of audioconferencing by teleworkers with physical disabilities.

TELEWORK

Telework has been widely promoted in countries such as the US, Australia, Finland, Japan, UK, Germany and India, as a means for reducing traffic congestion and air pollution, developing local economies, and improving competitiveness and business strategy (Higa et al., 1996). Telework provides the individual, the firm, and society with benefits such as increased flexibility, reduced real estate costs, and lower traffic saturation and environmental pollution. However, other researchers

have suggested that the physical distance resulting from telework creates interpersonal barrier for the teleworkers. The teleworkers may experience lower dependence on co-workers, lower trust levels, and an increased sense of detachment from their workgroup, jobs and organization (Kugelmass 1995, Ramsower 1984). Some of the limitations of telecommuting include isolation from the work culture, dissatisfaction with peer relationships, assessment concerns, individualistic mentality and more. However, telecommuting reduces travel time and can lower costs and increase productivity, among other benefits (Baruch 2001, Daniels et al. 2001). Most importantly, telework is an important adaptive strategy for people with disabilities for whom working from home is the preferred choice, or even a necessity.

Telework has open up new employment opportunities for people whose disability has excluded them from the workplace and also make it possible for people who become disabled in the course of their employment to retain their jobs in a new form (Murray & Kenny 1990). The main advantage of telework for people with disabilities has been noted as a sense of control over adverse life events (Bradford & Hesse, 1995). The flexibility in work environment allows people to minimize disruptions caused by the needs for attendant care and medical care, the lack of specialized transportation, and so on. In addition, employees can work at the times of the day in which they are most productive. This is especially important for those employees who require rest breaks throughout the day due to their medical condition. By working at home, they may work according to their own schedule. Bradford and Hesse (1995) also found that the participants in his study experienced more control over their lives, leading to greater productivity, better health, and increased morale.

However, telework can be demanding and requires that people with disabilities have an appropriate and accessible workplace at home, which may sometimes include a customized workstation and assistance in getting the equipment and materials needed to perform their work.

OVERVIEW OF TELEWORK FOR PEOPLE WITH DISABILITIES IN JAPAN

The Japan Telework Association (JTA) estimated that there were roughly 4.5 million teleworkers in 2005 with this number expected to increase to over 5.8 million in 2007. Many top executives in Japanese organizations highlighted telework as having the potential to become one of the main work styles for white-collar workers when asked to predict upcoming developments over the next 10 to 20 years (Higa & Shin, 2003). A study carried by the JTA in 1996 reported that the primary reason for companies to incorporate a telework system in their operation was reduction in office costs. Increased intellectual productivity and better physical and mental working conditions were other benefits noted.

According to the results of surveys conducted by the Ministry of Health, Labour and Welfare, published in the White Paper on Persons with Disabilities 2001, the total number of persons with disabilities in Japan is estimated to be about 5.6 million. People with disabilities in Japan are classified into three categories “physical disabilities” (including hearing & speech disabilities, and visual disabilities), “intellectual disabilities”, and “mental disabilities” (ILO & DCI, 2003). The same paper reported that there were approximately 3.2 million people with physical disabilities in 1996.

Various legal instruments are in place concerning the employment and training of people with disabilities. The Japanese Employment Quota System for Persons with Disabilities states that all employers must employ the legally required number or more of physically or intellectually disabled people as employees (JEED, 2005). The number is calculated as outlined below in Figure 1, based on the stipulated employment rate.

$$\boxed{\text{Legally required number of disabled employees}} = \boxed{\text{Total number of regular employees of an enterprise (excluding short-time workers)}} \times \boxed{\text{Stipulated employment rate (Private enterprise: 1.8\%)}}$$

Figure 1: Equation for calculating the required number of disabled employees.

Each organization is also required to submit an annual report on their employment of persons with disabilities. Many companies, as of the writing of this paper, still cannot fulfil the employment requirements and rather pay the penalties. In promoting equal employment opportunities, an allowance adjustment and reward system is designed to financially support the employment of people with disabilities. Various grants are also prepared for employers to help offset the expenses incurred by the improvement of work facilities or equipment and employment management in order to accommodate the special needs of workers with disabilities.

The JTA noted that commuting is one of the most serious problems for people with physical disabilities, especially for those having to commute into the centre of the city for work. Traffic jams and difficulty in finding a parking place puts a strain on people who use cars. The crowdedness and the lack of wheelchair access in public transit in city centres also pose difficulties for these people to travel. In general, facilities for people with physical disabilities, such as rest rooms and wheelchair access in buildings and stations, are insufficient. As a result, telework has attracted the attention of many companies as they work to accommodate workers with disabilities in their workforce. Many Japanese organizations are seeking to incorporate telework in their operation by allowing employees with disabilities to work from home. Telework is being targeted for activities such as research and development, analysis and designing of information system, editing of articles, and other work whose performance is largely at the discretion of individual workers (ILO & DCI, 2003).

ADAPTIVE TECHNOLOGY AND UNIVERSAL ACCESS

The advancement in technology in the past two decades is a phenomenon that has had considerable implications for people with disabilities. Different types of hardware and software are available to learn, to work and to engage in recreational activities. According to the Wikipedia, “adaptive technology” is the name for products which help people who cannot use regular versions of products, primarily people with physical disabilities such as limitations to vision, hearing, and mobility. Adaptive technology for those with mobility problems is of particular interest in the context of this research for employing an ICT that could support the collaboration of teleworkers with physical disabilities. Computer-mediated communications could remove some barriers imposed by physical and temporal distance for employees who are home bound or who have mobility impairments (Hesse et al., 1995). However, organizations need to provide suitable ICT to support teleworkers of the general population as well as people with different types of disabilities in the productive use of telework.

Practitioners of telework such as Oki Electric Industries Co., Ltd. (Hosono & Miki, 2004) have adopted the concept of Universal Design such that “the design of products and environments are to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design” (Mace, 1997).

Several other technical research and development projects have provided guidelines and insights towards the design of software applications for people with disabilities. The Adaptive Technology Research Centre at the University of Toronto is an example of a research and development centre that focuses on solutions applying user-centred design and universal design approaches to model and create solutions that are commercially feasible, operationally effective, and universally accessible (ATRC, 2006). The Web Accessibility Initiative (WAI) from the W3C is another active group in the area whose commitment is to lead the Web to its full potential includes promoting a high degree of usability for people with disabilities. The WAI, in coordination with other organizations, is pursuing accessibility of the Web through five primary areas of work: technology, guidelines, tools, education and outreach, and research and development (WAI, 2006).

In the review of universal access, Savidis and Stephandis (2004) discussed that the efforts are less prominent in the user interface design of software applications, as there are very few concrete examples demonstrating the benefits of a design-for-all approach to Human-Computer Interaction. Future technologies need to provide stronger and more seamless integrations of key collaborative capabilities, including better visualization and system accessibility, alerting and other visual cues in the user interface design. Applications are needed that can also assist specially challenged individuals transcend and overcome their disabilities.

AUDIOCONFERENCING FOR DISTANCE COLLABORATION

Audioconferencing is a form of distance collaboration that is both relatively inexpensive and widely used, particularly in business settings. Audioconferencing occurs in real time and thus facilitates rapid back-and-forth dialogue and exchange of ideas between individual group members by eliminating time lost between interactions (Kilgore et al., 2003). Since 2002 research has been conducted at the University of Toronto, seeking to enhance the quality of collaboration and knowledge dissemination between dispersed individuals by creating a light-weight audioconferencing tool that more effectively reproduce the benefits of traditional forms of direct, face-to-face communication. Appropriately designed audioconferencing may provide effective communication mediums for teleworkers with disabilities. The Vocal Village system was developed, as a result, to meet the goal of increasing both the communication effectiveness and the subjective experience of distributed groups.

The Vocal Village is an audioconferencing application that connects distributed groups over the Internet in real time. The uniqueness of the Vocal Village that distinguishes it from other audioconferencing applications is that its capability of providing spatialized audio in voice collaboration. The Vocal Village binaurally presents auditory location cues that cause the voices of individual participants to appear as if they are coming from different positions in space. As a result, participants' voices are distributed from left to right around the listeners' head. Within the Vocal Village environment (see Figure 2), users are able to independently arrange participants' incoming voice streams across the horizontal plain and view a graphical representation of the conference arrangement that includes participant names, positions, and relative volume settings (Kilgore et al., 2003). The field study reported in this paper concentrated on evaluating the usability and effectiveness of the Vocal Village audioconferencing system with respect to workgroup collaboration.

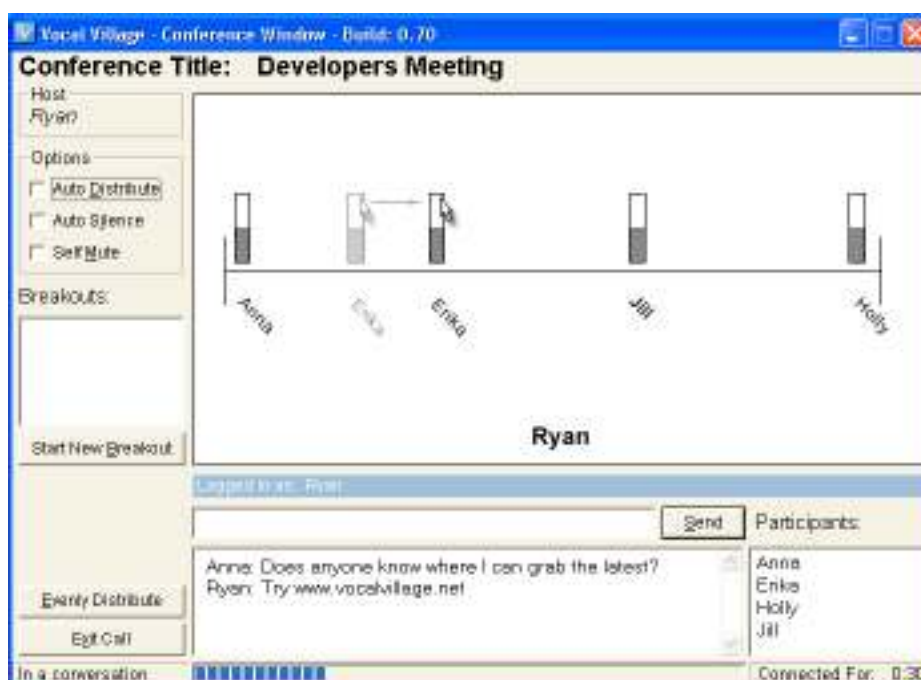


Figure 2: The Vocal Village Interface.

METHODOLOGY

A short field trial was conducted with a group of 7 teleworkers in Oki WorkWel Co., Ltd. Oki WorkWel, a subsidiary of Oki Electric Industry, is one of the first companies in Japan that specializes in employing teleworkers with severe physical challenges. Oki WorkWel currently employs 30 teleworkers. They work from home as Oki Net workers using their PCs and the Internet developing web systems, creating and consulting websites with high accessibility, and designing posters and pamphlets for clients. The seven participants in the study ranged from 23 to 38 years of age ($M = 31.43$, $SD = 5.65$) and lived with a variety of disabilities. Two participants were university graduates and five were high school graduates. They were all specialized in web design and web development with good knowledge of computer systems. These 7 participants had been working together as a team assigned by their coordinator prior to this study.

As an initial step to user requirements gathering, a semi-structured interview session was conducted with the project coordinators. The goal of this interview was to draw out the knowledge from the coordinators about the work practices of the Net workers including specific topics focusing on the net workers' methods of communication, training provided to the Net workers, as well as software and physical constraints when introducing a new application to Oki WorkWel.

Each of the Net workers who lived across the greater Tokyo area received a two-hour home visit. Face-to-face interviews with the net workers were conducted during the home visits. The home visits also made it possible to study how specific tasks were performed in practice, how the tasks were actually coordinated, and how patterns of cooperation came into play under actual conditions at their homes.

The outcome of the home visits and usage feedback led to the customization of the Vocal Village client as well as to the development of a task for the participants in the field study to perform. Modifications were made to the interface of the Vocal Village client to accommodate the suggestions from the interviews conducted. The English interface was translated into Japanese along with a few changes. They included: the use of visual avatars as shown in Figure 3, the use of wider volume bars to accommodate a lower degree of fine motor control, and the removal of the breakout feature. The changes were implemented in Visual Basic. The finished client was a prototype of a Japanese version of Vocal Village.



Figure 3: Japanese prototype of the Vocal Village.

In order to validate the changes made to the client, the Net workers were asked to use the prototype in their work practice, in particular, to use the Vocal Village in the completion of a project. The project was an “artificial” task put together by following the format of a previous project. The benefit of using an old project as guidance was to ensure the alignment between the Net workers’ skills and the scope of the task. The leader assigned roles to each member. They logged onto Vocal Village for one hour of their workday for a total of 10 days. The Net workers were encouraged to use the Vocal Village for voice collaborations such as discussions of issues, questions etc. However, how the net workers chose to allocate their working, talking, or meeting time was under their own control during the one-hour session with the Vocal Village.

RESULTS AND DISCUSSION

USABILITY EVALUATION

At the end of the trial period, the 19-item IBM Computer System Usability Questionnaire (CSUQ) was administered (Lewis, 1995). The net workers were asked assess the usability of the Vocal Village on a 5-point Likert scale. The questionnaire further allowed separate scoring of system usefulness, information quality, and interface quality and each net worker’s average scores for the three factors are shown in Figure 4.

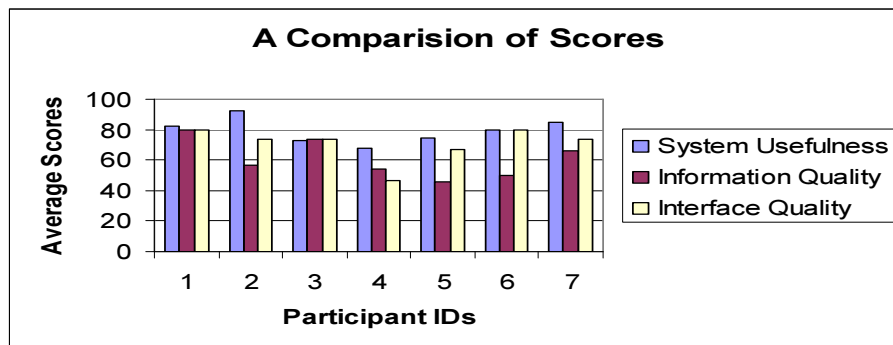


Figure 4: Scores on system usefulness, information quality and interface quality.

Evaluations on the information quality of the Vocal Village were lower than the scores of system usefulness and interface quality in general ($M = 60.88$). There appeared to be some disagreements on the information quality of the system amongst the members of the group. The factor of system usefulness tended to have the highest score amongst the three ($M=79.29$). The net workers were pleased with how easy it was to use the Vocal Village. Their scores indicated that they felt comfortable using the Vocal Village and judged themselves able to complete their work effectively and efficiently with this system over the trial period. Participant 2, particularly, gave a high score on this subscale. In terms of the interface quality of the Vocal Village, the scores were positive as well ($M=70.48$). The majority of the net workers, with the exception of participant 4, were satisfied with the interface of the system and thought the interface was pleasant. They also agreed that this system had all the functions and capabilities they expected it to have.

JOB SATISFACTION

The questions on measuring job satisfaction focused on the net workers’ subjective feelings with respect to four categories. They were the impacts of the use of the Vocal Village in their work in areas such as team support and dynamics; productivity and quality of work; communicating as a group; and the change in their feeling toward their work. The net workers were asked to rate a series of 24 statements that best describe their experience on a 5-point Likert scale. A score of one indicates significant deterioration in that category since they started using the Vocal Village in their task. A

score of three indicates no changes and a score of five indicates significant improvement in the corresponding category. The net workers' overall evaluation of their work satisfaction was positive concerning the incorporation of Vocal Village use into their assigned task. Figure 5 illustrated that there was no deterioration or weakening of satisfaction in any of the categories as compared with their regular work routine (See Figure 5).

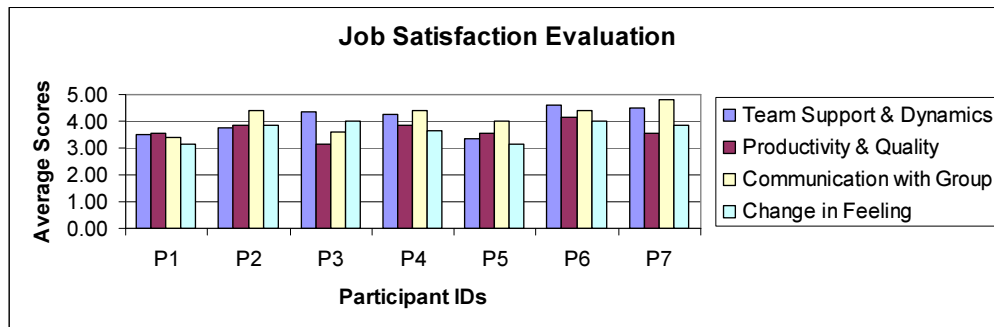


Figure 5: Average Job Satisfaction Evaluation.

The category with the most improvement was communication with the group. Most of the net workers felt that the difficulty in communication with others in the group had decreased with one member feeling that it had decreased greatly. Participants felt that their ability to talk to multiple people at the same time had increased greatly and that the ease of participation in a group had increased somewhat. The Vocal Village also increased their opportunities to express their opinions and to start enjoyable conversations with their team members. There used to be twenty to thirty e-mails sent amongst the group each hour on question-and-answer, that number reduced to three to four per hour. In addition, answers used to come from the leader only, but other group members started to contribute as well because they were able to talk and work at the same time.

Team support and team dynamics had shown the second largest improvement. Five net workers felt that the amount of assistance, feedback, and encouragement they received from their co-workers increased in the study. They agreed that they were able to learn from their team members more through talking to each other. Also, the amount of attention being paid to each other's opinions had increased greatly with the use of voice collaboration. More importantly, they thought their sense of being an important part of the team was increased as a result of the study.

The remaining two categories, productivity and quality, and change in feelings towards work improved somewhat according to the net workers' evaluations. The team leader noticed that the number of problems solved together with his team had increased greatly. The group felt that the quality of their individual work had increased moderately and it was a 50-50 split between "increased greatly" and "increased somewhat" for the quality of the group's work. They also thought that they had a better understanding of the overall objective and status of the project since the use of the Vocal Village. As their level of comfort in communicating with co-workers had increased, their sense of self-confidence and enjoyment of their work had increased somewhat as well. In addition, they noticed that their awareness of how their co-workers are thinking or feeling about their work had increased.

VISUAL DISPLAY

During each meeting, the net workers were asked to take a screenshot of their conference window. The screenshots gave a snapshot of the layout of the visual display of the participants on their screens. It was found that some net workers, in the majority of the meetings, placed the team leader at centre of the visual interface. When placed in the centre, the leader's voice appeared to be heard in the middle of the head, reflecting a dominant position, with more attention being paid to the leader.

In addition to consistently placing the leader in the centre, one participant showed a consistent strategy for positioning group members during the meetings where positions to the left and the right of the leader were consistently filled by the same participants. Thus, there is evidence that at least some workers find fixed assignments of colleagues to be useful for a succession of meetings.

MEETING RECORDINGS

All the meetings during the field trial were recorded on the Vocal Village server located on campus at the University of Toronto. Spectrograms of the sound files were generated by Goldwave, an open source digital audio editor. Each spectrogram visual displays one meeting's speaking activities over time. Figure 5 is an example of a spectrogram of a particular meeting. The horizontal axis is time in seconds (s), the vertical axis is frequency in Hertz (Hz), and the brightness represents the frequency's magnitude (dB). The louder a certain frequency is, the more intense its brightness is.

The recordings showed that the net workers were meeting for longer than the required one hour period in most meetings. The conference lengths ranged from one hour ten minutes to two hours. In each spectrogram, there are occurrences of times where the sound frequency was at 0 Hz, which means there were times in the meeting where no one was talking. The circles in Figure 6 highlight such gaps or quiet moments in a meeting. The same speech pattern appeared in all the spectrograms generated over the 10 day period. The shortest gap observed was between one to two minutes and the longest was approximately twelve minutes. After consultation with the net workers, it was determined that those were the times when they each were carrying on with their own work. In those cases, they had put the Vocal Village in the background of their work and muted their microphones. When they had a question or when their work was completed, they came back to the system to get feedback from the group. At that point a discussion occurred, and as soon as the issue was resolved they continued their own work with the Vocal Village running in the background.

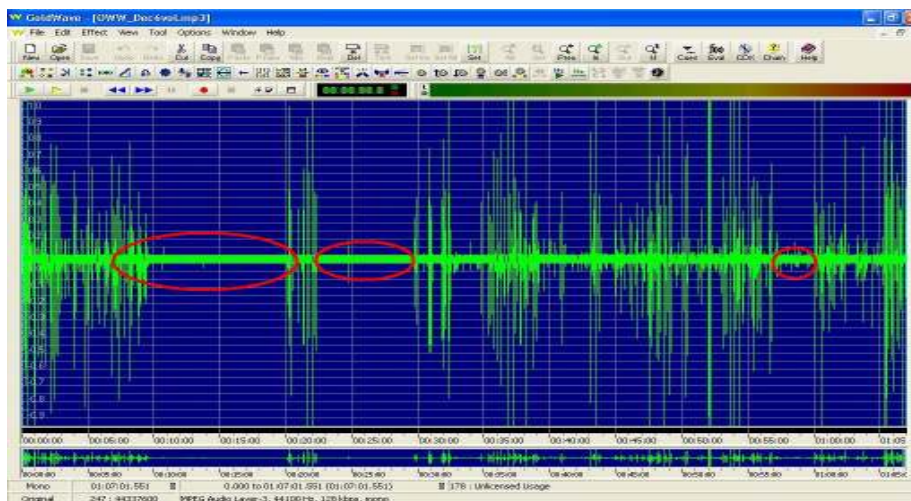


Figure 6: A spectrogram of the recording of a meeting.

CONCLUSION

In spite of its importance to business, there have been few attempts to customize audioconferencing to the needs of business. Business audioconferencing at present tends to use a telephone model, where there is no visual interface and no availability of even simple functions such as the ability to set the volume of conference participants independently of each other. The shortcomings of audioconferencing systems become even more pronounced in telework situations where there is not a room of co-participants in the meeting to provide support and non-verbal feedback. The situation is

even more difficult for teleworkers with physical disabilities, where there is a need to customized interfaces to audioconferencing systems.

In this field study we examined how a specially customized audioconferencing system could assist teleworkers with physical disabilities. One of the main lessons learned is that set up and installation is challenging and that involves individualized attention to the requirements of each teleworker. However, once the software interface was customized to the needs of this group, and setup and installation was provided to individual participants in their homes, good results were obtained. Trial participants communicated more effectively using the audioconferencing system and had to rely less on email, which was beneficial, since it was in all cases easier for them to talk than to type messages due to their physical disabilities. While a spatialized audioconferencing system was used in this trial, there was no control condition involving non-spatialized audioconferencing, thus we are not able to attribute the successful results to the use of spatialization per se. However, the present results do demonstrate the value of using a visual interface. Benefits included reminders of who the current participants in the conference were, increased social cues based on seeing pictures (avatars) represent others, and in some cases, the use of positioning within the visual interface as a way of reinforcing work roles.

The results in this field study demonstrate the potential value of customized audioconferencing systems to support teams of teleworkers with physical disabilities. Given that people with physical disabilities are frequently underemployed relative to their experience and abilities, telework is an important tool for societies to capitalize on these under-utilized resources while providing these people with richer and more rewarding lives. However, as the current study shows, it is important to provide appropriate, and appropriately customized, tools for these workers. Work from home can be socially isolating, and thus tools for enhancing communication and presence are particularly important. In view of this, further research and development of assistive audioconferencing systems for teleworkers with physical disabilities is urgently needed.

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