Accessibility of Non-verbal Communication: Making Spatial Information Accessible to People with Disabilities

Introduction to the Special Thematic Session

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Abstract. Non-verbal communication (NVC) is challenging to people with disabilities. Depending on their impairment, they are either unable to perceive relational gestures within performed by sighted people, or they are unable to perform gestures by themselves in such an information space (in case of motoric impairments such as cerebral palsy). Also other 3D gestures such as sign language and other aspects of non-verbal communication could provide an accessibility problem during training, interaction, and communication. This summary paper gives an overview on new approaches, how computers could mitigate these various impairments. Based on this we discuss how the papers accepted for this session relate and contribute to this new and challenging domain.

Keywords: Non-verbal communication · Cerebral palsy · Finger spelling

1 Motivation

Following the classical *3C model* [10], collaboration among humans comprises communication, coordination (scheduling, turn-taking etc.), and cooperation. The latter leads to artifacts that represent the intermediate and final results of collaboration, suggesting to distinguish a task space where these artifacts reside from the communication space – both of which may be real, virtual and/or imaginary depending on the setting. Consider a typical brainstorming meeting as a well defined and structured example of interaction and communication full of non-verbal elements, control tends to happen implicitly, following a

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social protocol (e.g., turn-taking by means of the first person to raise their voice after a sufficiently long pause); for simplicity, we will subsume it to happen in the communication space (for the case of brainstorming) hereafter. Turning to mixed brainstorming meetings between participants and people with disabilities, demanding challenges arise in both the communication and the task space (see Fig. 1). As the term *space* indicates, it can be enlightening to consider these two spaces in the narrow sense of the word, i.e. as three-dimensional (3D) constructs. As we will discuss below, serious disadvantages and even discrimination may result from restricting the mapping between participants and people with disabilities to one-dimensional accessible information what can be easily captured and conveyed in this form. Therefore, the session introduces suggestions to mitigate these deficiencies with a 3D approach.

In a lively brainstorming, artifacts such as sticky notes are generated, placed on common workspaces such as whiteboards and digital screens, and then discussed within the team (Fig. 1). While the artifacts are placed in the task space, the communication of the participants takes place in the communication space. Thus, the information flow in a team meeting is not simply on the generated artifacts and on the spoken explanations by the originator, but it is in particular a manifold of NVC, that could carry up to 55% of the overall information [3]. Gestures, facial expressions, postures, gazes, etc. are a huge repertoire of expressions performed in a three-dimensional space, from which some of them also refer to the 3D information space they are performed in.

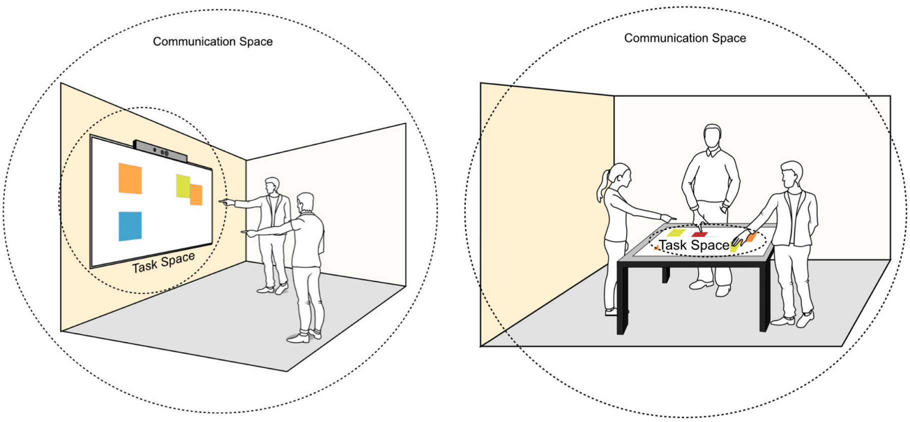

Fig. 1. Task and communication space within a team meeting [6].

While this interpersonal communication takes place in this communication space only, it typically also refers to artifacts in the task space. While this already shapes a three-dimensional information space, the artifacts in the task space make an additional dimension of complexity: The sizes of the artifacts, their distances to each other, as well as their position in the task space carry important information that also needs to be transferred to people with disabilities.

Within this session, three different accessibility problems will be addressed, and how they can be mitigated by means of assistive computer technology. While eventually future technology will allow these three different groups of handicapped people to communicate freely among each other, this session will introduce technologies to make 3D information accessible to (i) blind and visually impaired, (ii) motoric impaired (cerebral palsy), and (iii) deaf people.

2 Blind and Visually Impaired People

2.1 Related Work

There are multiple approaches to output the digital content of screens to BVIP, such as e.g. the outcome of the Tidia-Ae project [1], accessible classrooms [2, 12]. Many of the barriers described by [11] are still existent, or only partially addressed, for instance in an accessible tabletop [13,15], where natural pointing gesture of the sighted users on artifacts on a small interactive table could be detected and the relevant artifact's content output to a Braille display.

In order to detect a spatial relationship between artifacts, a Wii controller was used by [9], which outputs the proximity of artifacts to the blind user by vibration. Another approach by [16] uses cards with different tactile material, that again use near-field communication to communicate with smartphones. In order to allocate cards (of a mindmap application) on the table, [14] some active edge projection actuators to identify the card of interest on the table.

2.2 System Setup

During a brainstorming, sighted users refer to artifacts in the 3D task space by gazing or pointing gestures. These gestures are inaccessible for BVIP and thus need to be translated. Moreover, the task space is also continuously altered by adding artifacts or by clustering or removing them. The relationships of the artifacts to each other contains additional information, but this also has an influence on the NVCs. It is thus necessary to map all relevant NVCs to the artifacts on the common workspace and make their content accessible to BVIPs together with their spatial relationships. The proposed system consists of an interface for sighted users, as well as of an interface for BVIPs, which are both interconnected via the task space (Fig. 2).

The task space consists of two parts with two different views on the same content. For the sighted users it is the regular work space like an interactive whiteboard, while the part for the BVIP is a 2D horizontal output device that allows experiencing the spatial distances between the artifacts (Fig. 2).

2.3 Interface for the Sighted Users

The interface for the sighted users consists of the following components (Fig. 3):

- Input/editing device (smartphone or tablet) for editing the artifacts (cards),

– Screen for the facilitator to arrange cards in the task space (Fig. 1),
– Pointing gesture detection of the facilitator in front of the electronic whiteboard (Fig. 1).

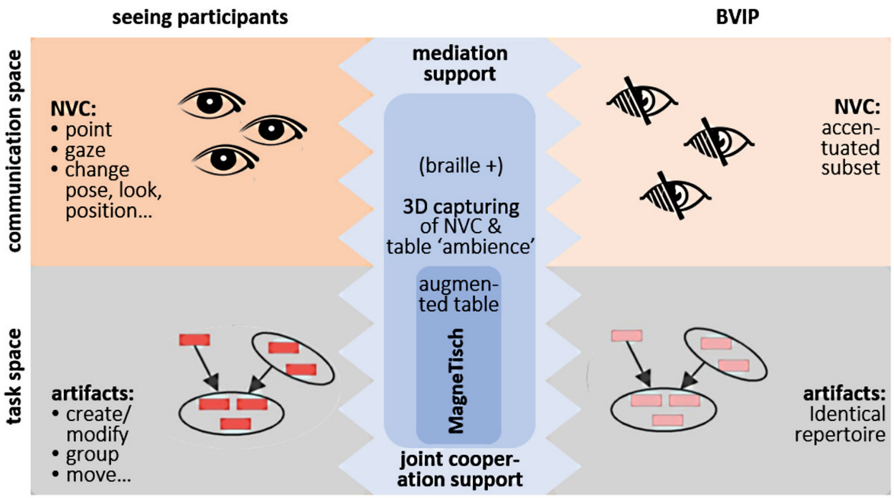

Fig. 2. Schematic system overview.

The card's are edited on a smartphone or tablet using the integrated keyboard of such devices. Only one or two words will be edited and then the card will be submitted to the shared task space. There, it will be further processed by the facilitator (Fig. 3). The facilitator will arrange the cards and initiate discussions. He is defining clusters and distances of the card's, as well as their positions on the screen. While arranging the cards on the whiteboard, he will eventually perform pointing gestures that need to be captured. While these pointing gestures are useless to the BVIP, they need to be related to areas on the screen that contain the generated artifacts. However, since pointing gestures are typically not performed precisely, it is sufficient to only detect certain regions on the screen. The system architecture is an open framework allowing to add new and additional NVC features for better inclusion of people with disabilities.

2.4 BVIP Interface

The BVIP interface consists of an interactive table on which a copy of the whiteboard content, i.e. the clusters exist. The table has an integrated x−y actuation system, which can magnetically pull a handle on the tabletop to any desired position. As soon as a pointing gesture from a sighted user in a cluster of cards is detected, the table is activated to move the handle to a region of interest. The BVIP's hand is then guided to a correct position to provide spatial information

Fig. 3. Editing of a card on a mobile device and a meeting room with an integrated whiteboard.

to him. For more detailed information of a cluster's content, the BVIP could then read out the content of the individual cards on his Braille display, or by using text to speech.

3 People with Cerebral Palsy

Cerebral palsy is a permanent movement disorder. Symptoms include poor coordination, stiff muscles, weak muscles, tremor, spasms, athetosis, etc. While frequently not being able to control muscles in a coordinated way, as e.g. for pointing gestures (Fig. 1), the research is focusing towards an augmentative alternative communication (AAC).

3.1 Related Work

To regain the possibility of selecting artifacts from the environment, research is mainly focusing on interfaces such as head movement and speech recognition devices, brain-computer interfaces [5], or eye tracking [8]. However, such devices are either too expensive, or too cumbersome to be used in a daily routine.

3.2 System Setup

In order to overcome the drawbacks mentioned in the above, the proposed system makes use of a 3-axes gyroscope, an HC-05 Bluetooth module, and a microcontroller Arduino Nano to make a complete data collection system for detecting head orientation. Using these components the head movement could be used to select commands or words and confirm the selection by nodding. The corresponding selection is shown on a screen to guide the user and to allow for a correction of his head movements. First preliminary studies with people having cerebral palsy showed promising results of this comparatively low-cost system.

4 Hard of Hearing and Deaf People

Following the World Federation of Deaf [19], millions of deaf and hard of hearing people use sign or signing supported language for communication instead of and/or in combination with written/spoken language. As a first example we focus on finger spelling as an important component of sign language, in which words need to be spelled letter by letter, which is in particular important for properly spelling names or other uncommon words [4]. However, finger spelling needs practicing in order to fluently communicate important information to others.

4.1 Related Work

Finger spelling relies on the movement of hand and fingers, and is thus more than just a sequence of still images [7]. Thus, training tools that just show still images for practicing such as [18] are not sufficient to train a finger spelling motion. Here, using animated avatars seem to be a promising solution for training such movements. However, existing solutions either just show an artificial hand instead of a whole avatar, or the avatar's torso shows a "robot-like" behavior [17], or the whole training system was bound to one single operational system, which hindered a widespread distribution.

4.2 System Setup

To overcome these shortcomings, a web-based solution is introduced that can be accessed from various operation systems to achieve platform independence. It is planned as an extensible framework allowing to integrate more NVC access solutions. Based on JavaScript WebGL2, the app allows also controlling the camera's perspective so that the avatar speller can be seen from various viewpoints

5 Contributions to Non-verbal Communication

The above outline, still restricted to well defined scenarios, shows the broad domain of NVC. A broad range of R&D is needed to address the challenge of making more aspects of NVC accessible and integrating them into AT supported environments for better exchange and participation. Due to the broad aspects of NVC, the contributions by nature address considerably different issues and thereby underline the need for a more holistic and integrating theory and concept of non-verbal communication for improved accessibility and inclusion.

The first paper focuses on accessibility of brainstorming meetings. It shows how pointing gestures by sighted people are retrieved and transferred to BVIP on a novel spatial output device. As a well defined setting in terms of timing, location, infrastructure and meeting participants but also in terms of procedures, artefacts and roles, this kind of meetings is an ideal playground for starting studies on NVC. The paper demonstrates one of the first approaches managing to bring the complexity of a collaborative meeting into an experimental setting allowing to support non-verbal communication aspects for BVIP users.

The second paper presents how interacting with and using a brainstorming tool by blind and visually impaired people (BVIP) can be facilitated. By combining the brainstorming software with a pointing gesture recognition system

BVIP participants reach a new participation experience during the brainstorming meeting when gestures are conveyed using Braille display and speech synthesis for access. This still experimental approach provides a new and innovative field for experimenting with new ways of better access and participation.

The third paper makes an emphasis on relating Augmentative and Alternative Communication (AAC) where people with severe motor and speech disabilities need innovative approaches in using alternative, body or body-near non-traditional and non-verbal activities for interaction and communication and in particular Human-Computer Interaction (HCI) based communication. Pointing gestures, tracked by a miniaturized sensor help people with cerebral palsy to precisely point at visible targets to enable several information flows. Any progress in tracking and making sense out of non-verbal communication cues and activities of users can be seen as a potential for new supportive functionalities.

The fourth paper integrates the question of access to sign language and finger spelling for deaf and hard of hearing people as an aspect of NVC. Using a web based avatar better training and learning should be facilitated. This at first reads distinct to the rest of the session, but consideration of a resource hosting, explaining and providing training on non-verbal aspects of communication is seen as of interest for all groups of users with disabilities in terms of a) understanding b) producing and c) integrating non verbal communication aspects into interaction and communication. The extensive work in the domain of sign language is seen as a candidate for a more structured and standardized approach.

6 Summary and Future Research

It is interesting and motivating to see how broad and diverse the call for papers for a session on accessibility of non-verbal communication has been. Tracking, presenting, understanding, doing and managing non-verbal communication aspects seem to be of particular interest for almost all groups of people with disabilities and seem to be of particular importance for facilitating active participation and inclusion. It seems to come much closer to the essence of inclusion into the diverse domains of our social life all based on very rich communication going beyond pure access to content as text, images, videos or other artefacts. More R&D is needed to allow people with disabilities to access, master and actively contribute to the full and rich range of non-verbal communication aspects.

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