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Supporting Communication in Rehabilitation Engineering Teams

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ABSTRACT

The objectives of this project were to examine how members of a colocated rehabilitation engineering[a] team communicate during their work and hence deduce the implications of these communications for the design of video-based technologies to support communication among members of a virtual rehabilitation engineering team. Twenty-four assessment clinic sessions conducted by rehabilitation engineering team were recorded on videotape over a period of 3 years. These tapes were analyzed in considerable detail using a schema to identify and classify the talk and actions of the team members. Combining talk and actions with artifacts[b] is a mechanism used by designers to develop ideas and communicate them to others. Speakers rely on actions to support and make their talk lucid. Cooperation based on sharing artifacts is a strength of face-to-face interaction. Participants can experience artifacts and observe others using the artifacts. Tools such as videoconferencing to support virtual rehabilitation teams will have to provide the participants with the ability to see often quite subtle gestures and actions if they are to grasp the meaning of the talk. Increased understanding how a team communicates visually complex data may (1) aid development of next generation videoconferencing equipment to better support distributed designers and rehabilitation engineers and (2) guide development of techniques to enhance the quality of visual data presentation in current videoconferencing systems.

INTRODUCTION

Rehabilitation engineering is often provided as a service to people with a disability in the hospital, university, or community health setting to evaluate, prescribe, devise, and provide assistive devices to increase their independence and reduce their handicap. Videoconferencing offers considerable potential as a communication tool in rehabilitation engineering, particularly where clients live in remote locations and experience difficulty in travelling to a city or regional center where assistive technology services are provided.[1] Whittaker and O'Conaill[2] detailed three ways videoconferencing might improve

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[a]U.S. Public Law 99-506 defines rehabilitation engineering as the systematic application of technologies, engineering methodologies, or scientific principles to meet the needs of and address the barriers confronted by individuals with handicaps in areas that include education, rehabilitation, employment, transportation, independent living, and recreation.

[b]An artifact is any physical object that a designer intentionally involves in communicating information to other participants of the design process, in this case other members of the rehabilitation engineering team.

communication. (1) Video supports behaviors, therefore it supplies nonverbal information; (2) video provides visible information about the environment and the availability of other people; and (3) video provides video as data about objects and events in a shared visual environment. Sellen and Harper[3] claimed the real benefit of showing work-related documents and objects in video-mediated communication was to provide a common frame of reference and a focus for discussion, rather than for the transmission of detailed information.

While the application of telemedicine to rehabilitation engineering provides promise, it also poses a unique set of challenges. The cross-discipline team-based approach plus the sheer physicality of rehabilitation service delivery causes it to be highly concentrated in a small number of centers, typically one per state in Australia. This limits access due to the cost and inconvenience of travel, especially in the case of individuals with a disability. Thus, rehabilitation engineering could benefit from the promise of telemedicine. However, these same defining characteristics make it quite different from "conventional" applications of telemedicine that typically involve the sharing of clinical data, especially images or real-time signals between a patient in a remote location and a clinician at a major hospital. In the rehabilitation engineering context, telemedicine draws far more heavily on the field of computer-supported cooperative work. For example, in rehabilitation engineering, the important issues revolve around developing a shared understanding of a client performing tasks and functions in order to design artifacts to enhance a client's activity. In human-computer interaction, "a science that designs and evaluates artifacts to help users do their tasks"[4] analysis of tasks helps the development of new tools (artifacts) that become the focus of study in the light of new situations and technical feasibility.

There is also much that telemedicine research can learn from the literature on the work of design teams. Previous empirical studies of design teams have highlighted the importance of physical objects as aids in the design process[5,6] and the role of gestures and actions.[7,8] These studies have focused on artifacts in terms of how they were handled or manipulated by designers, and provide insight into how artifacts need to be seen by the telemedicine participants for effective designing to occur.

Collaborative research between the Rehabilitation Engineering Centre at Royal Brisbane Hospital and the University of Queensland's Department of Mechanical Engineering has produced a detailed understanding of the way in which rehabilitation engineering teams accomplish their work.[8–11] The findings indicate rehabilitation engineering team members rely on action performed concurrently with their talk to enhance their communicating of complex shape, orientation, and location data. The acting with artifacts plays a significant role in aiding the design by generating ideas and providing feedback in testing ideas. Artifacts are used by individuals and shared among team members. The individual and shared use can be observed by other participants as "feedthrough," which is viewing the effects of actions by the users. This, in turn, can engender mutual understanding and a spirit of cooperation between participants. The context of this research was the provision of customized seating systems for children with severe disability. The insights gained through this work, including the exploratory application of standard videoconferencing facilities, point the way to the design of the type of infrastructure needed to support virtual rehabilitation teams (VRT). A VRT is a team whose members are distributed in time or geographically (or both) during the course of providing service to a client.

This article presents the results of a detailed empirical study of the relationship between the use of artifacts, gestures, and actions in design conversations and of the talk that accompanies their use. The results of this study suggest a set of principles that should be adopted if videoconferencing technology is to be successfully adapted to support virtual rehabilitation engineering teams.

MATERIALS AND METHODS

Data gathering

Video provides a means to record accurate detail of human interaction and capability to repeatedly scrutinize the detail for social action and activity. Numerous studies of naturalistic human activity have sourced data for analysis from videorecordings of the activity.[12–14] The cross-discipline, rehabilitation engineering teams were videotaped performing assessments of clients, during which information is gathered about the client and their specific equipment issues. The investigation of potential design solutions occurs by experimentation after considerable discussion. (Prototyping of customized devices occurs concurrently with the experimentation in the adjacent workshop.) Assessment involved examination of existing equipment, asking questions, discussion of experiences to elicit specific information about the client relevant to developing appropriate assistive devices. A prepared set of forms guided the assessment by prompting for the information to be sought from the client and care-providers.

Videorecordings were made using a videocamera with wide angle lens mounted high in the corner of the assessment room and focused on the location where the participants tended to group. A flat plate microphone fixed to a wall provided the sound input to the videocamera. Clients and care providers were asked in advance if they would participate in the videorecording and they signed informed consent documents. All participants were made aware of the presence of the videocamera before the assessment commenced. No further reference to the videocamera was made during an assessment session. Videorecordings were made of 24 assessment sessions, selected randomly, during a 3-year period. Work practices did change during that time due to normal events in a work place. Staff reflected on practice and implemented changes to improve the process, such as the prompts in the client fields. Staff changes occurred with therapy staff rotating through the clinic, however, the rehabilitation engineer and technician were constant team members across the recordings. No intervention was attempted to limit change or to control practice. While this may limit the reliability and validity of the data,[14] this was a study of practice of a rehabilitation engineering team and normal processes that affect a work group. Each client and care provider group was different and presented with different issues to be resolved, and there was large variation in the amount of investigation performed and the development of design solutions.

After the first year of the project, a small videocamera was made available to the team members to use at their discretion. Team members had experienced direct benefits from videorecordings by finding specific information that had not been documented elsewhere. Videorecording was embraced by team members as a useful tool for recording specific information about clients. The hand-held camera close-up data supplemented the wall-mounted camera that recorded the whole workgroup and showed most of the detail (verbal and nonverbal behavior) of the participants. Occasionally, data were lost because the viewfield was obscured when a participant moved between camera and the current activity or a participant chose to work at the far side obscured from the camera.

Data analysis

It was observed in each of the 24 videotapes that participants' communications concerning the work at hand frequently contained talking in association with actions. Sometimes participants made actions without talking. Seven of the videotapes with extensive segments of talking and actions were selected for detailed analysis. The total length of the segments in the seven videotapes was 2 hours 45 minutes. Data were extracted from the seven videotapes chronologically by transcribing the talk[c] of participants, describing the actions,[d] noting the artifacts used, and timing the length of talking and acting. Table 1 is an example of the action description style adopted to accompany the transcribing of talk.

Categorizing action. Whereas many artifacts were used, many actions were applied to them, within a wide range of talk-types, common and recurrent actions were easily recognizable. Cat-

[c]Talk transcription was restricted to oral output conveying information about the client, equipment, etc. Talking of a social nature, humor, etc., was not transcribed and was not included in analysis.

[d]Action is defined as purposeful hand and body movements performed with or without artifacts.

TABLE 1. DESCRIPTION OF ACTION ADOPTED IN TRANSCRIBING VIDEOTAPES

Time	*Speaker*	*Transcription*
1:00:40	Engineer (Engr)	He has been going into that sort of posture [ART Engr moves pelvis into sideways-sitting posture.] all the time which you know encourages that sort of curve [ART traces out curved line in the air with the spanner he is holding].
1:00:52	Occupational Therapist (Occ Th)	I'll put his arm up on the armrest [Occ Th walks over and grabs hold of Stephen's left arm at wrist and elbow and lifts it up off the left side seat and places it on the left armrest, straightening Stephen's trunk in the process.]
1:01:00	Engineer	That is something too he has got no where to he can't keep that arm on anything to help {Occ Th: the arm allows him to sit back.} the armrests don't go back enough [ART Engr moves right arm in a sweep from front of the wheelchair towards the back]. {Occ Th: Does that feel more comfortable now Stephen.} they are not padded big enough You know if he had something over that side [ART Engr has outstretched hand pointing over the side of the wheelchair] to support his arm in this sort of position [ART Engr extends same arm and points in general direction of Stephen's supported left arm which is now resting on the left armrest] then that would help. {Orthotist: Uhm.}

egories to code participants' actions used while communicating seating design information were developed based on evidence, visible or audible in observation of the videotapes, as proposed by Tartar.[16] Harrison and Minneman[5] studied the use of objects by a team of three designers during a videotaped design activity and devised a five-category system for use of objects in design. This system was expanded to six categories and modified to cover activities observed in the rehabilitation engineering videotapes that Harrison and Minneman did not consider. The six action categories and their indicative types of action shown in Table 2 offered an objective classification scheme that could be applied by observing the participants' actions accompanying their talk, or occurring in silence. The types of action listed in the right-hand column of Table 2 were developed by generalizing into simple, unambiguous movements and actions, all the actions observed across the videotapes.

Categorizing talk. A system to categorize talking arose from evaluating videotape transcripts and reviewing the videotapes to find obvious groupings. The development of both the action categorization and the talk categorization schemas was assisted by members of an engineering research practice group to refine the groups and the application of coding rules. Table 3 shows the final schema developed to code participant's talk.

The consistency of the categories chosen for coding the talk and action data were tested by comparing the coding applied by three test coders and the coding the author had applied. One test coder was familiar with the work at the seating clinic. The other test coders had had no exposure to the seating clinic. Each coder was: (1) given an introduction to the task they were to perform; (2) provided with notes on how to code videotape, event[e] by event (3) supplied a videotape of two clips of seating clinic video lasting 20 seconds and 2 minutes; and (4) given rating sheets with the transcript of each event on the videotape segments and space to mark their choice of classification of talk and action, and other details in each event. The correspondence of test coders with the author ranged from 51% to 83%, with an average of 66%. The coding of all the videotape data was performed by one of the authors (G.D.L.). The reliability of the refining of the raw data was tested by retranscribing and recategorizing videotapes and comparing the second-pass check with the first-pass records. It was found that 10% of events

[e]An event is defined as the occurrence of action performed in silence, or talk, or talk combined with action by a participant; an event continued for the time a participant was speaking and/or acting.

TABLE 2. CATEGORIES DEVELOPED TO CLASSIFY ACTIONS THAT PARTICIPANTS USE

Action category	*Types of action observed*
Constructing	Mock-up
	Hand shape
	Animation
Locating/indicating	Touch
	Tap
	Trace around
	Scribe marks
Measuring	Hand-to-hand span
	Hand-to-object distance
	Thumb-finger distance
	Using conventional measuring instrument
Demonstrating function (of equipment or the client's body)	Demonstrating a feature or situation
	Demonstrating a desired effect
	Applying force, push, pull, rotation, to show effect
	Pantomime (mimic a body orientation, function, action)
Examining	Handling an object to show its properties
Gesturing	Look at, glance toward an object, person
	Pointing to an object but not touching it
	Waving an arm at an object or person

required some reassignment of a data entry. The talk and action data extracted from the videotapes was stored in a relational database.

RESULTS

Introduction

This exploratory study used an observational methodology to avoid applying controls that might restrict the natural variability of practice in the real work group. An hypothesis was not developed around which data was analyzed.

Talk, talk, and action

The total number of events recorded was 882. This comprised 319 events where only talk was used, 41 events in which action occurred without talk, and 522 events where actions were combining with talk. Nearly 60% of communi-

TABLE 3. CATEGORIES DEVELOPED TO CLASSIFY TALK THAT PARTICIPANTS USE

Talk categories	*Defining features*
Design proposal	Contains data and concepts to specify a physical requirement to be constructed.
Dimension/location	An actual dimension or estimation of size, position, orientation of something that has design relevance and may be included in the completed construction.
Explanation	A response to a question or statement by another participant that provides additional information or should enhance understanding.
Information client	Information and data about the client's body that is important to the design
Information physical	Information about the physical environment of the client including equipment that is important to the design.
Comment	An unsolicited utterance that may provide additional information or be an opinion, or observation.
Question	Indication that something is unknown and should be known.

cating was performed using talk combined with action (hereafter labeled talk & action). In events where talk was developing or relating a design idea, the use of talk & action rose to 86%. Table 4 lists the use of talk, or talk & action according to the talk-type.

Table 5 shows the number of action-types that occurred for each talk-type in the videotapes analyzed. The top number in the data cells is the total of the action-type for the corresponding talk-type in that row. The bottom number (in brackets) is the action of the column's action-type for that row. This number termed the action value is the normalized amount of action per talk-type event and was calculated to enable comparison of action across talk-types with different totals of events. The value of the normalized cells was compared with the average of the normalized cells in the table, (ie, 0.274) to determine the existence of action patterns. The distribution of cells shows the following characteristics with respect to the average action value:

1. The Locate/indicate column contains action values two to three times the table's average value for talk-type Design proposal, dimension/location, and explanation, and between 1.08 and 1.7 times the average for the remaining talk-types. No other action-type involves such an extensive use in talk.
2. Indicating/locating and constructing action-types were frequently used with talk-type design proposal. The action value for these action associations is ranked highest (0.759) and second highest (0.635) in the whole table. Design proposals are associated with a below average use of the action-types measuring (0.146 action values), demonstrating function (0.183), examining (0.16), gesturing (0.248). Of these four, gesturing actions are used most.
3. As might be expected, measuring and locating/indicating actions have high association with dimension/location talk demonstrated by action values 0.622 and 0.556, respectively. The other action-types have very low action values for dimension/location.
4. Not surprisingly talk-type explanation involves very high use of locating/indicating actions (0.631) and moderate use of demonstrating function (0.288), examining (0.288), and gesturing (0.329) actions. Use of constructing actions (0.096) is very low.
5. Demonstrating function (action value, 0.556) actions are more commonly used in information-client talk than other action-types. Moderate use occurs of gesturing (action value, 0.333) and locating/indicating (action value, 0.296). No measuring actions occur with information-client talk.
6. Information-physical talk is accompanied by above average use of action-types locating/indicating (0.357), demonstrating function (0.375), examining (0.304), and gesturing (0.411). Action-type constructing has very low use.
7. The action-types gesturing (0.351), examining (0.33), and locating/indicating (0.319) are commonly used in talk-type comment. Demonstrating function (0.266) use was less common. Constructing actions (0.128) and measuring actions (0.085) were rarely used.
8. Talk-type questions shows moderate use

Table 4. The Number of Events (Occurrences) of Each Talk-Type in the Data

Talk-type	*Number of events*	*Percentage*
Design proposal	161	19.2%
Dimension/location	53	6.3%
Explanation	97	11.5%
Information-physical	92	10.9%
Information-client	42	5.0%
Comment	222	26.4%
Question	174	20.7%
Total	841	100.0%

TABLE 5. ACTION-TYPES USED WITH TALK IN TALK & ACTION EVENTS ANALYZED IN THE VIDEOTAPES

	Action-type					
Talk-type	*Constructing*	*Locate/ indicate*	*Measuring*	*Demonstrating function*	*Examining*	*Gesturing*
Design proposal	86	104	20	25	22	36
No. of events: 137	(0.635)	(0.759)	(0.146)	(0.183)	(0.16)	(0.248)
No. of actions: 293						
Dimension/location	5	25	28	2	10	4
No. of events: 45	(0.111)	(0.556)	(0.622)	(0.044)	(0.222)	(0.088)
No. of actions: 74						
Explanation	7	46	13	21	21	24
No. of events: 73	(0.096)	(0.631)	(0.178)	(0.288)	(0.288)	(0.329)
No. of actions: 132						
Information-client	2	8	0	15	7	9
No. of events: 27	(0.074)	(0.296)		(0.556)	(0.259)	(0.333)
No. of actions: 41						
Information-physical	3	20	8	21	17	23
No. of events: 56	(0.054)	(0.357)	(0.143)	(0.375)	(0.304)	(0.411)
No. of actions: 92						
Comment 12	30	8	25	31	33	
No. of events: 94	(0.128)	(0.319)	(0.085)	(0.266)	(0.33)	(0.351)
No. of actions: 139						
Question	6	40	5	9	29	24
No. of events: 87	(0.069)	(0.456)	(0.058)	(0.103)	(0.333)	(0.276)
No. of actions: 113						
Total action in talk and action events	121	273	82	118	137	153

The average value of action-type actions per event of talk-type is 0.274.

of locating/indicating actions (0.456), examining actions (0.333) and gesturing actions (0.276). The other action-types are accompanied by low action values indicating very low usage in this talk-type.

These action patterns observed in the data of Table 5 prompt the following comments:

1. The result shows the work of design proposal attracts the highest usage of two particular action-types, locating/indicating, and constructing.
2. Locating/indicating actions are important to all the talk-types; they have a wide spectrum of application and very high usage in the talk-types that could be considered to offer explicit information.
3. Measuring has a narrow spectrum of use. The high use of measuring action in talk-type Dimension/location was expected but its lack of use in other talk-types is perplexing. It would reasonably be expected that measuring would feature strongly in design proposal because measuring provides specific detail about size and location. The zero use of measuring in information-client is a reasonable expectation because the physiotherapy and occupational therapy assessment when physical features of the client were examined was excluded from the videotape acts and vignettes analyzed.
4. Design proposal and dimension/location talk have high association with action-type groupings, constructing and locating/indicating, and measuring and locating/indicating, respectively. In both talk-types the pair of action-types with very high use contrast with the below average involvement of the remaining action-types. The high action value indicates these action-types appear to have specific association with these talk-types. For example, constructing actions are clearly associated with design proposals, measuring actions are clearly associated with dimension/location, and locating/indicating ac-

Table 6. The "Role of Action" in Relation to Talk Identified in the Videotapes Analyzed, Shown for Each Talk-Type

Talk-type	No. of events	"Role of action"			
		Gives meaning	Identifies talk	Embellishes	Unrelated
Design proposal	138	80 (58%)	36 (26%)	16 (12%)	6 (4%)
Dimension/location	45	24 (53%)	9 (20%)	9 (20%)	3 (7%)
Explanation	73	33 (45%)	20 (27%)	11 (15%)	9 (12%)
Information-client	27	14 (54%)	11 (38%)	2 (8%)	0
Information-physical	56	19 (33%)	22 (40%)	9 (16%)	6 (11%)
Comment	95	30 (32%)	39 (40%)	14 (15%)	12 (13%)
Question	87	27 (31%)	45 (52%)	9 (10%)	6 (7%)
Total	521	227 (44%)	182 (35%)	70 (13%)	42 (8%)

tions are important for both talk-types. The other action-types do not appear to be as important in communicating design proposal information and dimension/location information. The dichotomy is not repeated in the other talk-types.

5. The high action value for locating/indicating associated with explanation talk and high action value for demonstrating function associated with information-client talk suggests information communicated in these talk-types is reliant on certain types of actions. These talk-types show near-average action value, for most of the other action-types hence they are different to the case above for design proposal and dimension/location talk.
6. Gesturing has less specificity than the other action-types and enjoys almost universal application across talk-types. Its near-average action value in six of seven talk-types suggests gesturing plays an important role, though at this stage of analysis the role is elusive. It may be being used as a social modifier to attract and maintain attention.

The value of action to talk

The importance of action to a corresponding piece of talk was determined by considering the understandability of participants' talk without and with observing their actions. In multiple-action events, the influence of all actions on understanding was considered. Each action was not individually considered. Four outcomes of listening were considered:

1. If the talk on the videotape (audio with no images) made no sense, and on replaying the tape observing the action accompanying the talk enhanced the understanding of the talk, then the action was rated as "gives meaning" to talk.
2. If the talk on the videotape made sense as English expression but the meaning of the talk was unable to be established without seeing the action, then the action was rated as "identifying the talk." For example, the action could clarify what part of a wheelchair was being talked about or the location of an object.
3. If the talk alone made complete sense and that sense was unchanged after seeing the action, the action was rated as "embellishing the talk."
4. If the action appeared to be unrelated to the talk it was given a rating "unrelated."

The "role of action" in the talk of the analyzed videotapes is presented in Table 6 and indicates that in 79% of the events, seeing the action was necessary to understand what was said. (In 44% of events the actions "gives meaning" to talk and in a further 35% of events seeing action is needed to "identify the talk.") Action embellished an event in 13% of cases. In 8% of events the action appeared to be unrelated to that talk of the event.

Combining the results of Tables 5 and 6 indicates talk-types with high action value, ie, design proposal, dimension/location, explanation, information-client, and question also have high values for role of action. Thus, the talk that is most likely to communicate ideas and information for rehabilitation engineering designing is likely to be reliant on action to add lucidity to the talk.

These outcomes indicate the extensive use of action with talk by the participants to enhance their communicating. They also indicate the need for participants to visualize action in order to attain the dialogues full value.

Pronouns and adverbs and deictics

Sample transcripts from videotape segments were examined for grammar. Pronouns such as it, this, and that and adverbs such as here, there, and up were words commonly used in the talk. The majority of these events contained a high incidence of locating/indicating actions providing a reference for the talk's focus. Harrison and Minneman[5] also noticed designer's frequent use of these vague terms "here," "this," and "there" and the pointing, holding, and making of shapes with fingers and hands that occurred in concert with talk. Tatar et al.[17] commented that, "the success of a deictic reference depends on the shared knowledge about the position of the object." In face-to-face practice, concurrent action provides visual cues about location and meaning of participants' talk. These links require attention be given to the indeterminent nature of pronoun and adverb content of speech. Either participants need to modify their discourse word selection with more identifying nouns and adjectives to increase understandability, or the videoconference technique has to ensure a speaker's actions concurrent with their characteristic pronoun- and adverb-containing talk are clearly visible to other participants.

Artifacts. Artifacts were implicated in many actions. Approximately 83% of actions in the talk & action events involved an artifact. The artifacts used by participants to assist their action were usually the objects around which discussion was currently focused. Artifacts served to focus attention of the clinic participants, stimulated question-answer dialogue, and drew out participant's experiential knowledge and considered opinion. Observation of many designing episodes where it was evident there was close association of artifacts at hand with an idea or sequence of ideas proposed by team members, provided evidence of roles of the artifacts in aiding the design process. These were: (1) to initiate discussion and discovery; (2) to stimulate generation of new ideas; (3) to verify information and understanding; (4) to develop and propose ideas.

Team members using artifacts, individually and in groups of two or more gathered around the wheelchair discussing and trying out ideas, helped build a common (shared) reference and mutual understanding about design possibilities, design and manufacturing decisions (specifications), and achievable outcomes. The high usage of artifacts in the rehabilitation engineering work is an indication that artifacts add value, probably because they assist participants to increase the complexity of data communication through creating visual reference points to underpin oral descriptions. Face-to-face interaction of participants is strengthened by the ability to physically share an artifact. Team members can work together on a problem by asking questions, developing answers, all the while using the artifact(s) to test ideas and extend thinking to new solutions. The same benefit of using artifacts cannot be had in video-mediated interaction because some physically isolated participants can see the artifacts in use but are unable to physically share them. Some alternate means to replace physical interaction may have to be developed to assist this aspect of designing by videoconference.

DISCUSSION

Although there is not a direct connection between the rehabilitation engineering team working face-to-face with a client and care providers and the same team videoconferencing with a client, it is reasonable to suggest the modus operandi of face-to-face interaction will carry across, or there will be attempts to carry it across to videoconferencing because it has proven over time to be effective in achieving good outcomes for clients. Understanding face-to-face rehabilitation engineering practice and the techniques of effective communication of team members that contributes to successful outcomes for clients can benefit new methods of service delivery, such as using videoconferencing to work with clients at a distance. If designing custom seating and other assistive technology can be done at a distance, it will offer significant benefit to those clients who live in remote regions and people whose medical situation presents travel risks. This research shows the colocated rehabilitation team makes great use of the ability to dynamically access the client and the other physical artifacts of interest, eg, the existing wheelchair and seating systems. Team members and the client group combine talk & action frequently to communicate details that can form specifications for manufacture. Videoconferencing does not readily allow actions such as finely executed movements to be seen distinctly so there is potential for some of the subtlety of the visual component of the communication to be lost or misunderstood. Specific hardware or operational methods may need to be applied to videoconferencing to bring it to the level of effectiveness of the colocated team.

The Rehabilitation Engineering Centre has conducted six videoconferences with distant clients aimed at evaluating mobility and seating issues, and where possible, acquiring measurements and other data to use in constructing custom seating in isolation from the client. Reflection on the analysis of face-to-face rehabilitation engineering practice and experiences in these initial videoconference sessions suggest some procedures that may benefit users of videoconferencing:

- Develop an explanatory document outlining what is to happen and why, the limits of the process (what is hoped to be achieved), the role of the remote group, and instructions outlining the rules of conduct for videoconferencing. Documentation for consenting to image storage is advisable.
- Send a blank client file to the remote therapists so they can think about and plan for the information to be discussed during the videoconference to complete the file.
- Run a test videoconference with the remote site therapist (at least the first contact) without the client, to establish rapport and basic understanding of how the client session will run, where the client group should be positioned for the camera setup, etc. Alert the therapist to the visual richness of the client assessment and the rehabilitation engineering team's desire to capture visual data on the videoconference camera. Practice some routines in instructing the therapist to apply and manipulate some of the tool kit artifacts so these commands will be expected and understood during the client videoconference. Test run with the therapist the taking of client measurements and shapes to ensure the correct techniques are being used.
- Seek feedback from the remote site immediately at the conclusion of the videoconference to get an appreciation for what they felt happy with, uncomfortable with, etc., to incorporate next time.

Conventional videoconferencing technology does not, in itself, afford equivalent access to the crucial details for a team that is not colocated with the client. One solution would be to develop complex video systems with multiple cameras possibly complemented by sophisticated (and expensive) devices for gathering three-dimensional information (about the seating) and then communicating that from the remote location. A more appropriate and cost-effective approach is to augment as-provided videoconferencing facilities with process improvements in the workflow and management, together with the use of common methods at each of the sites. The future direction of this research is in the development of web-based knowledge and workflow management tools to be used in association with a physical tool kit common to all participants (remote and local) and complemented by videoconferencing technology.

The web-based tools will provide resources for therapists who want to link in with the Rehabilitation Engineering Center. The tools include electronic case notes that enable participants in a client's rehabilitation process to share data and information (including visual data) to keep abreast of clinical opinion and decision making, document templates for making referrals and ordering services and equipment, evaluation reports and specifications of wheelchairs and other assistive technology. The tool kit contains measuring instruments, a range of (artifacts) seating hardware (selected in response to information provided in questionnaires sent to the client and care providers), and instructions for the use of these items. The toolkit is sent to the remote group to use either serendipitously or under instruction from the rehabilitation engineering team. A digital videocamera is provided to: (1) take video of the client in the home, school, community environments (to be shown during the videoconference) that will influence design ideas and (2) link into the remote site videoconference system to provide a high-quality picture for seeing detail at the Rehabilitation Engineering Center.

The concept is to develop a system of working that incorporates videoconference techniques for rapid communicating across a distance and web-based tools for information and knowledge sharing. This concept has benefits over developing a new, dedicated technological solution because emerging assessment and telecommunication tools can be readily incorporated as and when they become available. The approach also accommodates the development and delivery of professional development programs on assistive technology into the workplace, particularly for healthcare professionals working alone or in isolated locations where professional development opportunities are currently severely limited.

The results of this research indicate that the participants incorporate artifacts into their conversations and act on the artifacts as part of the idea generation process, and apply this action to aid communication of ideas. Participants also place great reliance on the capacity of their actions, particularly supported by artifacts, to make their talk lucid. The absence of the "copresent environment"[18] of face-to-face meeting makes for considerable challenge in successfully accomplishing cooperative work that has high reliance on visual data and talk, using videoconferencing technology. Current communication system bandwidths limit the visual performance of videoconferencing so increasing the number of cameras to capture all actions by remote participants provides no benefit. Sharing experiences with artifacts is less efficacious for videoconference participants than in the face-to-face scenario. A degree of "sharing" can occur if both local and remote site participants have immediate and direct access to the same artifact, which is the role of the tool kit artifacts, and all participants can see what the actor is doing with the artifact. For this reason simple etiquette, ie, keeping participants and their actions in the view field of the camera, helps maintain the common reference between the remote group and the city-based rehabilitation engineering team. The naturalness of face-to-face interaction involves complex mediation of which gesture and turn-taking mechanisms are two components. Extensive development of both technology and techniques is required to make video-mediated communication in work relying on talking and visual data, perform to the same level as a copresent team.

CONCLUSION

Talk & action based on simple artifacts is a mechanism for designers to develop ideas and communicate those ideas to others. Speakers place reliance on actions to support and make lucid their talk. Cooperation based on sharing artifacts is a strength of face-to-face interaction. Participants can experience artifacts and observe others using artifacts. Thus support tools for virtual rehabilitation teams will have to allow participants to see often quite subtle gestures and actions if they are to grasp the meaning of the talk. Current videoconferencing systems do not do this well. Development of videoconferencing technology needs to be directed to accommodate the talk & action mechanisms used in rehabilitation engineering designing.

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