Introducing COGAIN – Communication by Gaze Interaction

ABSTRACT

This paper introduces the work of the COGAIN "Communication by Gaze Interaction" European Network of Excellence that is working toward giving people with profound disabilities the opportunity to communicate and control their environment by eye gaze control. It shows the need for developing eye gaze based communication systems, and illustrates the effectiveness of newly developed COGAIN eye gaze control systems with a series of case studies, each showing differing aspects of the benefits given by gaze control. Finally the paper invites the reader to work with COGAIN in developing gaze based communication systems to enable and empower people with disabilities.

KEYWORDS

Eye gaze, assistive technology, augmented communication, COGAIN

INTRODUCTION

Communication by Gaze Interaction

Communication by Gaze Interaction 'COGAIN' (www.cogain.org) is a European research Network of Excellence that is aimed specifically at enabling effective, rapid and natural communication and control via eye gaze for users with high-level motor disabilities. The aim of this paper is to introduce the work of COGAIN and to present the services and expertise of COGAIN to users, workers in the field and researchers.

COGAIN consists of researchers and industries from 20 universities, institutions and industries from across Europe that have come together in a 3 million Euro 5 year project to develop new ways of enabling communication, environmental control, and personal mobility all based solely on using eye gaze. Much of our work concentrates on advanced development of existing techniques for gaze based communication with the needs of the end user driving the work. The project focuses on improving the quality of life for those whose life is impaired by motor-control disorders, such as Amyotrophic Lateral Sclerosis (ALS) (also known as Motor Neurone Disease or Lou Gehrigs disease), cerebral palsy, multiple sclerosis, or spinal injury by developing gaze driven assistive technologies that will empower users to communicate by using the capabilities they have, and by offering ways of compensating for capabilities that are deteriorating, all at a completely new level of convenience and speed via gaze-based communication.

COGAIN has four main aims – first to form outreach groups and networks to work with disabled users, workers in the field and rehabilitation centres to assess and identify their communication and control needs and abilities, second to use these findings to develop new methods and systems for communication and control by eye gaze, third to produce new hardware and software eye driven systems that are for the first time both low-cost and freely available, and finally to publicise widely the use of gaze communication for users and researchers interested in eye gaze communication - so that they may work with COGAIN and exploit our resources and outcomes in a combined effort toward greater and more enabling technologies for motor disabled users.

The motivation for COGAIN

The ability to express oneself quickly and efficiently in a precise language is fundamental to quality of life; however some people with high-level motor disabilities such as ALS or locked-in syndrome for example are not able to carry out such interpersonal communication fluently. Within Europe alone there are estimated to be over 16 million people who could benefit from gaze based communication and control [1] (Table 1).

Condition	Approx Number
ALS/ MND (Amyotrophic Lateral Sclerosis)	54,000
MS (Multiple Sclerosis)	13,700,000
CP (Cerebral Palsy)	1,140,000
SCI (Spinal Cord Injury)	18,000
SMA (Spinal Muscular Atrophy)	41,000
Rett Syndrome	68,000
Stroke	618,000
TBI (Traumatic Brain Injury)	916,000
*** Total**	**16,550,000**
* Out of overall total of 450 million people in EU	

Table 1. Number of people in Europe who could benefit from eye gaze control [1]

Of those 16 million people (Table 1) many find efficient communication extremely difficult and frustrating, with some users almost unable to communicate in conventional ways due to their disabilities preventing control over movement. Access to the information society through the Internet may be severely limited or be impractical by an inability to use the normal controls of a computer. These problems are compounded by currently available eye-enabled applications, which are limited in the extent to which they suit both the range of different user requirements and the range of user disabilities, resulting in a greatly reduced availability of suitable systems and so limiting uptake of eye gaze by disabled users. This is illustrated (Figure 1) where the overlap between existing gaze control applications, the requirements of existing users from applications, and the range of different user disabilities is small. Addressing these profound communication needs of users with high-level disabilities is the motivation behind the COGAIN network, with the aim of greatly increasing this available overlap of suitable systems and user requirements and abilities.

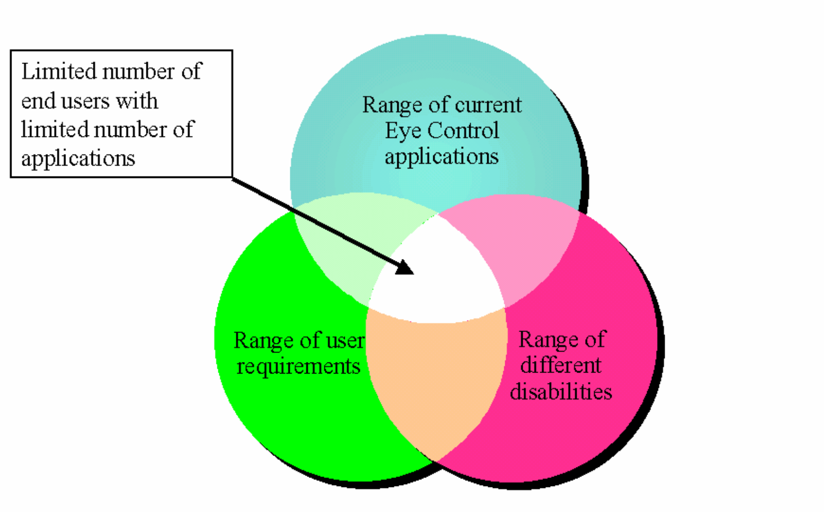

Figure 1. Current restrictions of eye gaze communication [2]

THE BENEFITS OF GAZE COMMUNICATION

The benefits of eye gaze communication can be illustrated by case study, as the information acquired from users provides a valuable insight into the impact of eye control technology on quality of life, and valuable direction for eye gaze control research both within COGAIN, and across a wider field of research areas. In each of these case studies all participants have given full permission for their images and information to be used in order to show the benefits of gaze communication.

Birger

Birger suffers from ALS and now, due to progressing motor paralysis, can only communicate with a few trained professional carers (communication partners) via tiny eye brow movements, producing words and commands slowly by spelling and intuition (Figure 2).

Figure 2. Birger communicating by eyebrow movement via a communication partner

Birger uses a row and grid matrix arrangement of letters written on a piece of paper (Figure 2). Firstly the communication partner asks Birger which row the letter is located in by calling out: “First?…second?.....third?...” and when the target row is mentioned Birger raises his eye brow. Then the communication partner reads out the letters along that row for example, “m...n...o...p...q...r”? …and again Birger looks upward when the right letter gets mentioned. With familiarity, the communication partner can make a guess in order to complete a word or sentence, once Birger has begun spelling. If this guess is correct, Birger can raise his eye brow to confirm the guess. If it is wrong, a downward look tells the communication partner to go on. Other users with ALS sometimes prefer frowning instead of looking up and down as they may have better control of their forehead muscles [3]. The advantage of this system is that it may be used everywhere and it costs nothing. The disadvantage is that it takes time for the user and communication partner to master it (especially without the paper in front of them). This type of communication does require considerable mental concentration from both partners. From our observations, typing speed varies. In some cases, when the user expresses daily needs in a well-known context it may be several words per minute. If irregular words and/or original thoughts are to be expressed, it may be just a few words per minute. Finally, the user, in this case Birger, cannot communicate without his communication partner, leaving him no privacy and totally dependent on another person to express himself.

COGAIN partners have addressed these needs for communication, and using the most recent eye gaze communication software from COGAIN Birger can now communicate effectively via eye gaze using 'GazeTalk' [4,5] (Figure 3). Birger uses the GazeTalk software with a standard 'Quick Glance' gaze tracking system [6]. He has considerable experience with the system, having used it for over a year, and continues to use the system to date. The GazeTalk system is a predictive on-screen text entry system that has only ten large 'buttons' filling the complete screen, with text entry and control via a predictive system that provides the most likely 'next key' dynamically on screen when needed. The main reason for using only ten large keys on the keyboard layout is that it enables the use of an eye tracker with a low spatial resolution (for example a low-cost web-camera based eye tracker) and also reduces the visual accuracy and effort required by the user to use the keyboard.

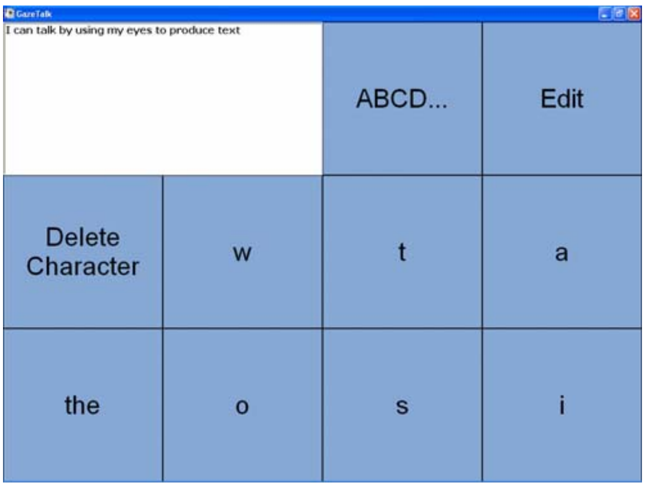

Figure 3. The GazeTalk keyboard [4,5]

From feedback from users such as Birger, GazeTalk has been expanded from a text entry tool to a feature-rich primary augmentative and assistive tool for users, with gaze controlled features such as: writing and speech output (with letter and word prediction, and word completion); specially designed gaze controlled email, web browser and multimedia player; and with environmental control of the domestic environment of the user (heating lighting, entertainment systems, house doors, alarm etc) to be added in 2007. It is a clear demonstration of the enabling power of eye gaze – with this system Birger can free himself from reliance on others for communication (Figure 4, left) can type text and email freely (Figure 4, right) and use the internet, and will soon be able to control his domestic environment independently – opportunities that were impossible before his eye gaze communication system was developed.

Figure 4. Enabling technology: communicating by eyebrow movement and now communicating by eye gaze alone

Keith

Keith has ALS and is completely paralysed, being only able to move his eyes. He can no-longer move his head at all, and he cannot blink, and it is necessary to keep clearing his eyes in order to prevent a film building up on them, making communication extremely difficult.

He now uses a MyTobii [7] gaze tracking system similar to Birger's system for communication extensively, often up to 12 hours daily and has considerable experience with the system. Keith now regards eye-control of his computer as essential to his quality of life: "I would have no desire to live without this eye-gaze system", and uses it for a range of activities, such as social communication, writing, emailing and access to the Internet. Eye-writing using an on-screen gaze driven keyboard is his "only way of communicating". It enables him to "still be a part of other people's lives. Plus, I can still give advice and help others". Through emailing, he keeps in daily contact with people: "It gives me an outlet to feel like I can still make a difference on somebody's life". The Internet is his "only way of keeping up with what's going on in the outside world". Eye-writing is quicker for him than when he was able to use his fingers to type: "I am faster with my eyes than I ever was when my fingers used to work". Whilst he has not timed the number of words per minute he achieves, Keith has the dwell select time (the time he needs to fix his gaze on a key before it is pressed) set to a very short 0.20 seconds, which suggests an extremely proficient user able to find and select keys with great accuracy and speed. In the experience of COGAIN, achieving such a speed with any other pointing method than eye control (for example a head-mouse) would be very difficult indeed. Eye-writing is quicker for him than when he was able to use his fingers to type: "I am faster with my eyes than I ever was when my fingers used to work".

Keith has asked COGAIN researchers if it would be possible for him to control his wheelchair using his eyes, as it would provide him with "freedom from always having to ask others for help". He would also like to be able to use eye-gaze to take control over his environment "so I could be more independent…to change TV channels, turn lights on and answer the phone". From input by Keith and others, both personal mobility and personal environmental control are now solutions that are being addressed by COGAIN researchers, with gaze controlled environmental control solutions due to appear in 2007, and mobility control later in 2008.

Claire

Claire has athetoid cerebral palsy, which means it is very difficult for her to control her movements. She is very bright, literate and well motivated. She uses a special joystick to access the computer. Using the joystick and a range of specialised on-screen grids she is able to use the joystick effectively and accurately to control the computer. Nonetheless, the method is very time consuming and involves a great deal of physical effort for her because, with her particular condition, there is a great deal of involuntary movement whenever she tries to carry out a manual task. Just reaching out in order to grasp the joystick handle in the first place is, in itself, very difficult, with her hand and arm sometimes 'overshooting' the target. It isn't just hand movement that has this effect. Even if Claire just tries to speak, this also triggers off a range of involuntary movements and this, too, can be tiring for her. In contrast, when there are no physical movement demands on Claire, she has learnt to sit reasonably still with comparatively little involuntary movement. Researchers in COGAIN have found indications that Claire's voluntary eye movement does not cause involuntary movements of the body in the same way as when trying to move a hand or arm for example. This suggested that eye gaze may both allow communication for Claire, and also relieve her from her involuntary body movements caused by trying to manipulate a joystick, (Figure 5, left).

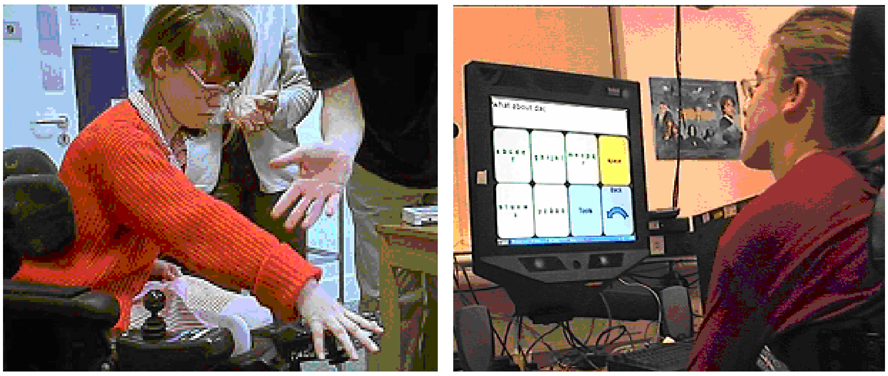

Figure 5. Claire using a wheelchair joystick, and using eye gaze [7, 8] to communicate

When eye tracking was tried with Claire, using a MyTobii [7] gaze tracking system driving on-screen keyboard software ‘The Grid’ [8] customised by COGAIN [10], the results were encouraging (Figure 5, right). The system did manage to cope with a certain amount of involuntary head movement, whether forwards, backwards or sideways. When she tried eye-writing, despite the cognitive load of concentrating on eye-typing using an initially unfamiliar on-screen keyboard she still managed to remain comparatively still. Nonetheless, the targets had to remain reasonably large to maintain accuracy and communicate using an on-screen grid (Figure 6, left). Although Claire could, with effort, access smaller targets using eye control at present she prefers to use large targets (Figure 6, left) and to access the letters with "two hits", one to select the group of letters and then another “hit” to select which letter from that group she wanted (Figure 6, right). Claire has used the system occasionally for over a year and has now become quite proficient. Claire's successful typing has already showed strong indications that eye control may be both quicker and less tiring (because of the sharp reduction in involuntary head movement), and more comfortable for Claire, and Claire continues to use the system to communicate.

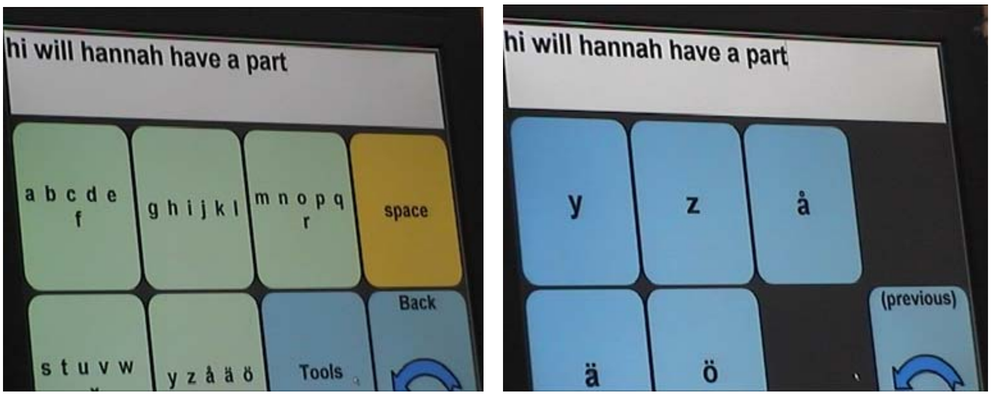

Figure 6. Claire using large on-screen keys to type [7]

Michael

Michael is in his early 40's and has a wife and three boys. He had a severe stroke about 2 years ago and now, after rehabilitation, is back at home. Before his stroke, Michael was very active and enjoyed a wide range of leisure pursuits. Despite the stroke, he remains a very intelligent man with an excellent sense of humour. He would like to be able to access his computer quickly and efficiently in order to communicate socially and assist with his wife's business. However, at present, his only form of access to technology is via switches. Michael cannot speak but communicates by looking at letters on an 'E-tran frame' (Figure 7, left). The E-tran frame is a deceptively simple system of communication that utilises eye-pointing. A transparent frame printed with letters and coloured areas is held between the non-speaking person and their communication partner. The communication partner looks through the frame into the eyes of the non-speaking person, enabling full eye contact. In use the non-speaking person is first asked to look at the block of letters that contain the letter first letter of the word they wish to communicate. They then look at the coloured spot that corresponds with the colour of the letter. The communication partner monitors the eye direction of the user and may be able to guess the word, or the non-speaking person can carry on to the next letter. In this way, complex conversations can be held. This he finds very slow and frustrating and would very much like to use eye control as a quicker and easier method, if at all possible.

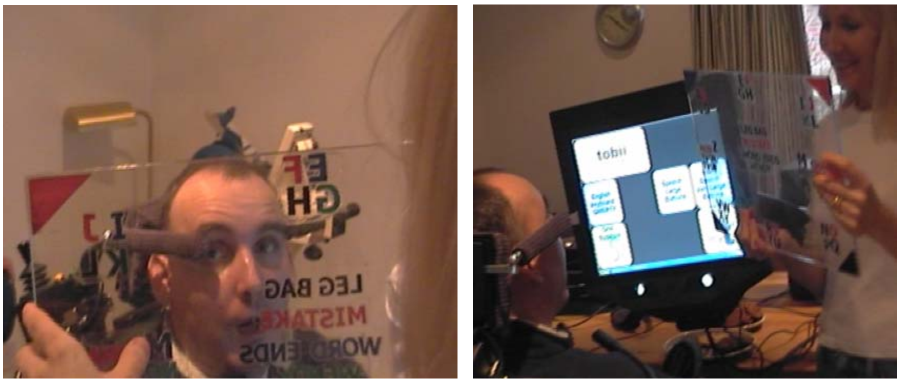

Figure 7. Michael using his E-tran frame, and using eye gaze, on-screen keys and the E-tran together to communicate

Because of his stroke, Michael has a certain amount of difficulty with head control. In addition, he has nystagmus, which means that he cannot fix his gaze in the same way that most other people can. Both of Michael's eyes have a significant amount of involuntary side-to-side movement (nystagmus) which tends to become more severe when he is tired (Figure 8).

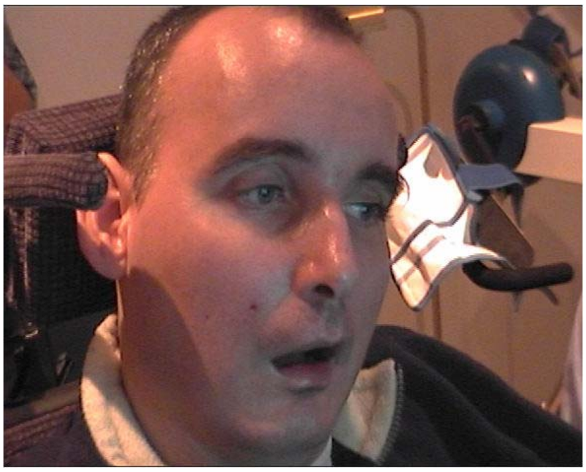

Figure 8. Close up of Michael's eyes - despite his nystagmus, the eye tracker managed to provide a functional calibration

Several eye tracking systems were tried with Michael, with little success due to his nystagmus. Finally, a ‘MyTobii’ [7] gaze tracking system was tried (Figure 7, right). The system was modified by the manufacturer from advances made within COGAIN so that if there are any specific areas of the screen that required re-calibration, due to eye calibration drift or poor tracking, they can be selected and recalibrated individually. This presented a solution to his nystagmus allowing correction of calibration only at defined inaccurate areas of the screen whilst preserving existing accurate calibrations on the rest of the screen (Figure 9).

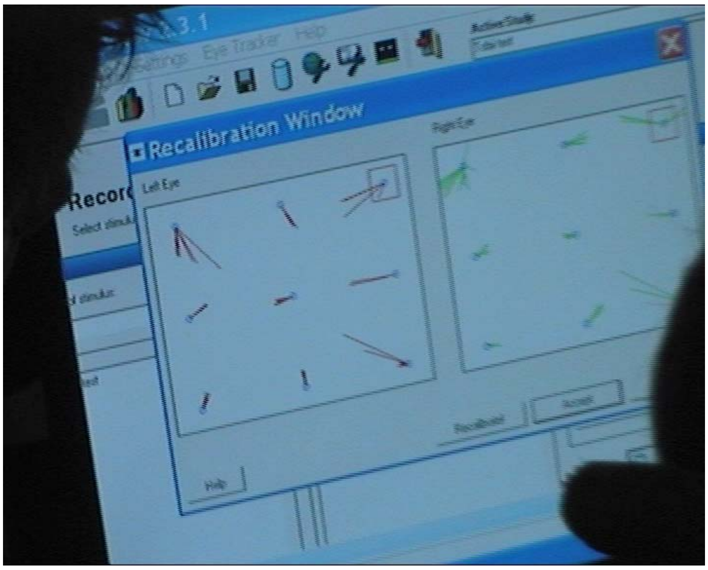

Figure 9. The facility to recalibrate only inaccurate areas enabled Michael to use the eye gaze system (note the small square at the top right, illustrating the area of the screen that needs to be recalibrated)

When communicating by typing Michael, due to his visual and physical difficulties, prefers to use a “three hit” way of writing using larger key targets filling the screen (Figure 10).

Even though he could hit smaller targets and access letters with only two hits, as with the grid that Claire uses (Figure 6) he prefers the larger targets because, overall, he doesn't have to concentrate so hard on his accuracy. As a result, he can therefore write for longer periods of time with more satisfaction because it is less hard work and he makes fewer mistakes.

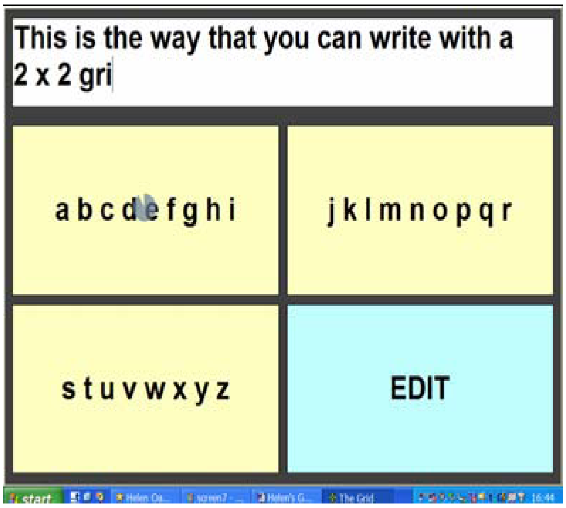

Figure 10. Michael's keyboard, using very large targets and multiple hits to select a letter

However, even if a successful calibration was achieved, account must be taken of the fact that the nature of Michael's visual difficulties fluctuates and a successful calibration at one moment in time might not work effectively for him on another occasion. For example, in the morning, the system was able to produce a calibration that was accurate enough for Michael to be able to select a letter he required for eye-typing with two hits, for example selecting a cell with the letters A-F and then selecting the actual letter he wanted. Unfortunately, when it was tried in the afternoon, Michael's involuntary eye movement was greater and finding a calibration that would enable him to reliably access the same size of cells proved very difficult. The reason for this can be clearly seen (Figure 11). Here calibration accuracies are shown for the left and right eye in the left and right hand boxes respectively, with the lines radiating away from the nine target circles on each screen showing the amount of pointing inaccuracy away from those target circles. The upper picture shows good calibration from a morning session, the lower figure shows degraded calibration from an afternoon session where Michael was tired.

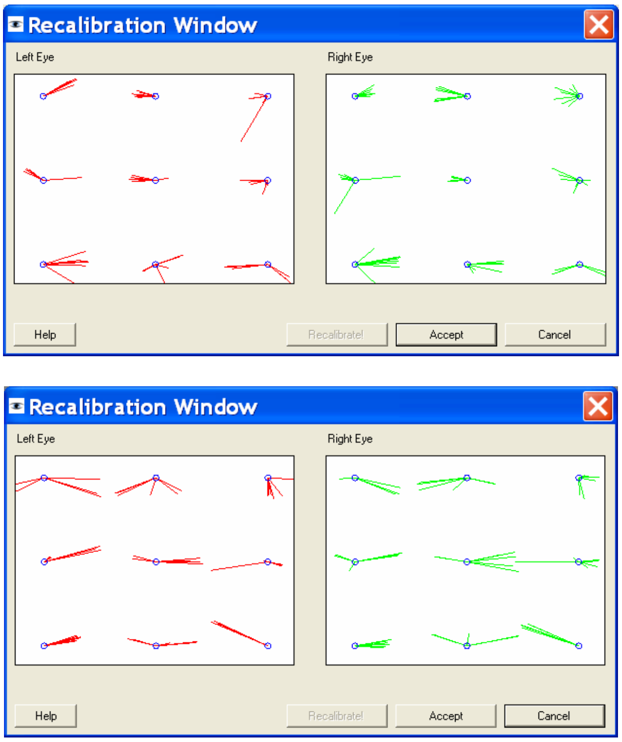

Figure 11. Decreasing calibration accuracy with increasing fatigue for Michael

On the occasions when Michael did achieve a successful calibration, the significant increase in speed that he was able to achieve in comparison with switches, combined with his greater comfort and satisfaction that the eye tracking system and software gave him, meant that he was extremely enthusiastic about eye control as an access method. Due to the high cost of the system Michael has not been able to afford a system of his own and relies on the loan of systems from COGAIN. His enthusiasm emphasised the importance of the need for developers within COGAIN to try to accommodate people like Michael by taking his kinds of access difficulties (involuntary head movement and fluctuating visual difficulties) into account.

Ahmar

Ahmar is interesting because he has a comparatively mild form of cerebral palsy and normally would not be considered for eye control. He is an excellent head-mouse user and has used a complex on-screen keyboard [9] (Figure 12, upper figure) successfully for many years. However, when he tried eye-control for the first time, using a 'MyTobii' system [7] coupled to a simple grid [8] (Figure 12, lower figure) he was immediately convinced that, for writing at least, he would use eye control if he had the opportunity as it was faster and required less effort.

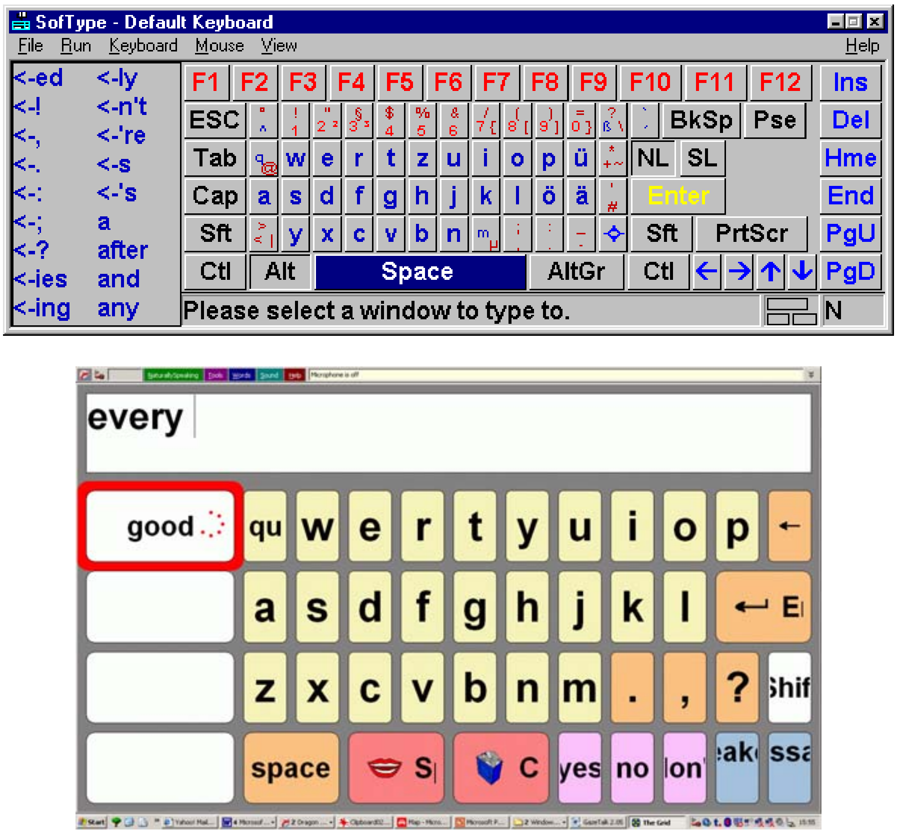

Figure 12. Eye-typing for communication and head pointing for other tasks

Given a choice, Ahmar said he would switch between eye-control for writing and head mouse control for all his other needs. His views are particularly interesting in that there are over 1 million people across Europe with cerebral palsy. It would be of great benefit to give those people the opportunity to complement their existing communication and control methods with eye-control if they were given such a choice. Ahmar still uses his head mouse, but also uses gaze control when it is available to him. Due to the high cost of the system he has as yet not been able to afford a system of his own, and is hoping for lower cost systems to become available.

WHAT CAN COGAIN PROVIDE?

As illustrated by the case studies, COGAIN and its researchers operate by putting the needs of the end user first and foremost (Figure 13). User needs can be seen as being surrounded by layers of their personal environment, their support infrastructure (such as communication enablers) and their wider environment that both restrict and may also enable communication. It is the aim of COGAIN to enable communication across these layers as easily an effectively as possible. The case studies clearly show that without their input and criticism we would be unable to design, produce and promote eye gaze systems that really work. It is important for COGAIN to remember that, despite the benefits that some people with disabilities are already enjoying though the use of eye control technology, many of those who would gain most benefit from its use are still excluded from using it. It is hoped that, by working closely with these potential users, many more of them will be able to use eye control technology by the time the project is completed.

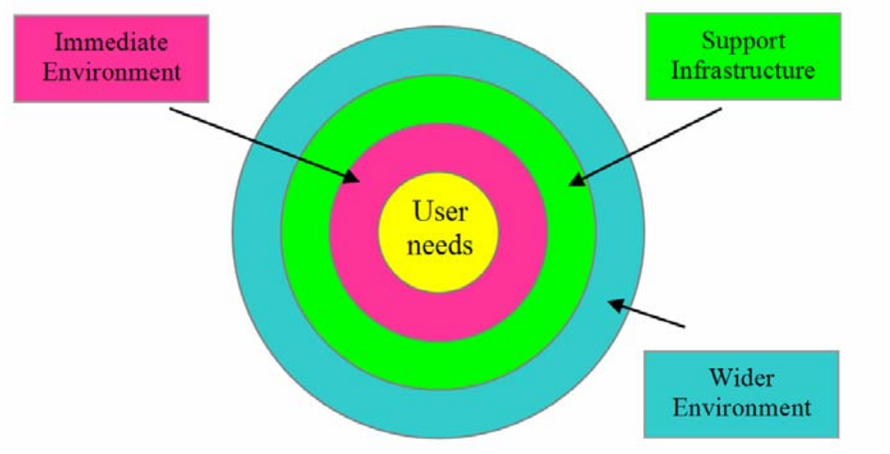

Figure 13. COGAIN places the needs of the end user first [10]

COGAIN aims to provide a path to workable, practical and low-cost eye gaze communication and control solutions. We are working in areas that include:

- *Increased use of gaze driven technology in everyday life.* Here COGAIN is promoting gaze tracking as a viable means of communication. Often gaze tracking has been regarded anecdotally as difficult to use, but with advances in technology from commercial manufacturers and COGAIN based communication enhancements gaze tracking is now becoming ever more useable.
- *Development of very low-cost ubiquitous gaze trackers* that will bring down the cost of gaze systems and make them available to all. To accomplish this COGAIN is developing low-cost gaze tracking systems based on free COGAIN software and low cost (less than 100 Euros) web cameras [11].
- *Develop tools for rapid and natural text generation* (typing, editing), and multilingual text generation (typing, editing). Here COGAIN is making freely available via its web portal text generation tools such as Dasher [12] and Gazetalk [4, 5, 13] that are

available in many European languages as well as Japanese, with continued development adding more languages.

- *Develop gaze aware and attentive interfaces* that will remove the need for either 'dwell clicking' or a secondary button to enable clicking on interface objects. This will be accomplished by inferring the intent of the user from their actions and the state of the interface [14].
- *For users with less severe impairments*, to provide a possibility for multiple modalities (e.g., gaze in combination with speech, or head pointing) [15] to be used in conjunction with gaze to aid interaction and control of an interface.
- *Develop gaze driven edutainment applications* (such as games, shoot 'em up, crosswords, music generation) that will supplement basic communication needs with entertainment and learning facilities. Games will be developed that are more suitable for gaze control (having easy to locate large target objects for example). Such an example is the COGAIN chess program [16] (Figure 14).
- *Develop virtual environment gaze driven interfaces* for research, natural interaction and edutainment applications [17]. COGAIN aims to extend gaze driven interfaces from the 2-dimensional world of the desktop screen to the 3-dimensional world of virtual reality. This will enable users to interact with virtual worlds and experience scenes and adventures that they may not otherwise be able to participate in.
- *To take gaze control from the desktop and into the real world:* COGAIN is developing gaze driven methods for control of personal environments (for example gaze driven home automation) and control of personal mobility (for example gaze driven wheelchairs) to increase the autonomy of users.

Figure 14. The COGAIN EyeChess program - playing chess by eye gaze alone [16]

SUMMARY

COGAIN is working towards giving people with profound disabilities the opportunity to communicate, and control their environment and mobility by eye gaze control. There is a need for effective and efficient gaze based communication with over 16 million people in the European Union potentially finding efficient communication extremely difficult and frustrating due to motor disabilities. These people could benefit from gaze based communication. The case studies shown here are all different, reflecting the very diverse nature of disability, but all have a common thread of communication being enabled by gaze. Before using gaze Birger, Keith and Michael all used labour intensive manual communication systems that required a highly trained communication enabler to be with them when they wished to communicate. This greatly restricted their remaining independence. COGAIN tried gaze systems, based on available commercial systems coupled to COGAIN modified interfaces, with Birger, Keith and Michael and found that all three people benefited from gaze communication provided that their communication interfaces were specially designed for gaze control – with large target areas tolerant of gaze tracking inaccuracies. Claire had used a joystick to communicate but found it very difficult, and

Ahmar could use head tracking quite effectively. When they both tried gaze based communication they found it easier than their existing methods. For Claire gaze did not trigger her uncontrolled body movements, enabling her to relax and communicate well, and for Ahmar it allowed him faster communication than head pointing. These diverse case studies show that state of the art gaze tracking systems coupled to suitably designed gaze driven interfaces can now enable very effective communication, but at a high cost for the systems and with limited features available. From this demonstration, COGAIN is moving further forward to develop low-cost gaze tracking systems with enhanced features such as gaming and environmental and mobility control, all based on user involvement at all stages of development. COGAIN aims to enable widespread, more effective, and more application areas for communication by eye gaze for high-level motor disabled users than have been available before.

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