LOOK IN, TURN ON, DROP OUT

Alastair Gale and Fangmin Shi

*Applied Vision Research Centre,
Loughborough University,
Loughborough LE11 3TU
UK*

The ART (Attention-Responsive Technology) research project is developing a system to enable mobility-impaired individuals to access technology efficiently. The system monitors both the individual and any ICT devices in his/her environment. It then uses the individual's gaze direction to determine to which ICT device, if any, they are potentially attending. This information is relayed to a user-configurable control panel, which then displays only those controls that are appropriate, both to the user and to the particular device in question. The user can then choose to operate the device if s/he wishes. The initial ergonomic challenges in the development of the ART system are described.

Introduction

The title re-iterates Timothy Leary's 1962 exhortation to individuals to forego their normal working routines and follow his psychedelic lifestyle approach. Here the quotation is used with similar sincerity but in a markedly different fashion – to describe the operation of a control system (ART – Attention Responsive Technology) under development which is designed primarily for use by disabled users (Gale, 2005a).

The system selects a device for control by means of the user simply gazing at an identifiable electronic device (an ICT device or 'object') that they want to operate ('look in') so enabling it for potential use. Then the user can operate that device if they so wish ('turn on'). One of the key issues for the approach is the question of both selection and operation accuracy and the potential for errors ('drop out'). It is therefore this last issue which forms the key interest considered here.

What are the potential ergonomic issues which will impact on the actual deployment of such a control system and that will give rise to possible errors? An 'object' here is taken to be any ICT device or related electrical piece of equipment in the user's environment and which could be operated by the ART methodology. An error is seen as the selection by the ART system of the wrong object, non-selection of an intended object or incorrect operation of a correctly selected object.

ART

The ART system and its operation have been described in outline previously (Gale, 2005b; Shi et al., in press; Shi et al., 2006). A user's eye gaze behaviour is monitored automatically and when this is measured to fall on a particular ICT object then the user is offered a dedicated interface simply for that object. Thus, where the user looks governs the selection of an ICT object for possible operation but not its actual operation, hence overcoming inadvertent operation of objects (c.f. Jacob, 1990). If s/he wishes to operate the selected object then they can do so by various interface methods tailored to the specific needs of the individual user.

What then are the potential sources of error in the use of such a control system? This paper describes the main issues which are foreseen as being important.

In parallel, a survey is currently under way of potential end users to glean information about what they would like such a system to offer them and also the issues that they foresee in utilising the ART system.

Challenges

In the initial stages of development it is assumed that our target user is:-

- Mobility restricted in some way, although possibly moving about the environment – for instance, in an electric wheelchair.
- In terms of physical movement - potentially only capable of moving their eyes but could have some other restricted physical movement (e.g. limited hand movement but with no real physical strength with which to operate interfaces).
- Wishes to operate and control various systems autonomously without the need for another person's intervention.

For the ART system the difficulties anticipated relate to:-

- The potential user
- The Environment
- ART system accuracy
- ICT objects

Potential users

Users of the ART system are targeted as being anyone with mobility problems or a mobile person in an environment where, for some reason, they are restricted in their physical movements. However, the key driver for the development is individuals with severe mobility issues.

The extreme of such conditions are those persons with Locked in Syndrome (LIS), as first identified by Plum and Posner, 1966. Such quadriplegic patients are very rare and have no mobility, except for the voluntary use of eye movements and blinking; however the patient remains alert, generally with a good prognosis for long term (>5 year) survival after the first year (Hemsley, 2001). Murthy et al. (2005) report a recent case which indicates the potential rapid development of the syndrome.

There are different kinds of LIS: 'classical' locked in syndrome where patients can only move their eyes vertically as well as their upper eyelids, 'incomplete' (where other eye and eyelid movements are possible) and 'complete' paralysis (no movements). Patterson et al.

(1986) reviewed 139 cases of LIS and emphasised the need for an effective communication system for such patients, an issue well addressed by COGAIN (2004).

The ART system would potentially then be of use to a wide cross section of individuals, including other patient groups (e.g. spina bifida patients) where the person has some degree of restricted mobility but, importantly for the project, has voluntary control over their eye movements.

User Environment

A key question is in what environments would ART be used by potential users? Two eye movement monitoring systems are used (Gale, 2005b) in the development of the ART system so that the product will be of use to a great number of users and in a wide range of situations. Both methods utilise the principle of directing incident infra-red (IR) illumination at one or both eyes of the user and then monitoring reflections of this light from the front and other ocular surfaces of the eye/s. The level of IR used in such commercial eye movement systems is very low and well within acceptable standard safe limits. However, it is easy for such an approach based on IR to be overwhelmed when used externally, for instance on a bright sunny day, by the IR naturally present in sunlight which can cause the system to fail to monitor the user's eye movements appropriately so giving rise to potential error. Hence such systems, whilst operable externally, are most easily used indoors.

Consequently, it is initially envisaged that three environments are probably important, namely; living, working, and the kitchen. Therefore, the ART approach would have to deal adequately with any/all ICT objects in these environments that a particular user may wish to control independently.

ART Accuracy

The ART eye movement system must be capable of accurately identifying where the user is looking so that the appropriate object is selected. The key question here is just how accurately must the system measure eye gaze behaviour?

All eye movement recording systems produce some output indicating the point of gaze of a user with some degree of accuracy. There is always some inherent error in measuring eye gaze depending upon a number of factors including the particular recording technique used. Equally, all systems require calibration before use by an individual. To do this the user looks at a matrix of points in space (typically arranged in a planar 2D square about 20-25° visual angle in size) and their gaze locations are recorded. Software then compares the known locations of the calibration points to the system's recorded gaze locations and performs a transformation between these two matrices.

After calibration then subsequently all recorded raw gaze locations are first transformed by the software according to the outputs from the calibration trial. For accurate eye gaze measurement then good calibration is a necessity. However, good calibration usually requires some degree of compliance by the user and this may not always be possible for the deployed ART system. For instance it is always difficult to know when an individual is actually fixating on a calibration point when instructed to do so and this is particularly the case if the user has communication difficulties.

Consequently, can poor calibration or even no calibration be used in the ART approach and if so is the resultant accuracy level of user gaze location acceptable? One of the advantages of the ART system is that objects for the user to select between can be spatially distributed about the environment, therefore in principle it is possible to array objects around so that relatively poor estimated measurements of where someone is looking could be used to select one object from many.

The potential for error therefore depends upon the number of objects, their size and spatial arrangement. In order to be able to distinguish between a user attending to one of several overlapping objects, or objects in close proximity, will require quite accurate eye gaze recording.

ICT Objects

Clearly it is essential to know which ICT objects are important to the specific user as well as knowing which ICT objects potential users currently use and which they would like to additionally use through implementing the ART system. The frequency of operation of each object in a given time period is also important and could lead to error. For instance, electrically operated curtains may only be opened and closed once a day by the user, therefore not necessarily requiring a fast responding control mechanism to the user's command.

The speed of selection and operation of a particular object may be important for some and not for other objects. The current speed of selection and operation of objects by a user's current communication/control system would be taken as a metric against which to measure the ART system's performance. The failsafe operation of an object is also an important consideration. ICT objects may also need to be operated by others apart from the target end users and so other additional interfaces may be required for their helpers or family members.

An advantage of the ART approach is that an object can be selected for operation by such an eye gaze contingent system when the object is at some considerable distance from the user, as long as the measured gaze location – including an allowance for overall measurement error (essentially the object's 'operational zone') - does not overlap the operational zone of an adjacent object. For some objects this will be eminently suitable (e.g. opening/closing curtains or operating room lighting levels). For other objects, whilst these could be selected at some distance, the actual useful operation of them would require that these be near to the user or else errors will result.

Conclusions

The ART system is just in its second year of a three year development process and progress to date has concentrated upon finding state of the art technical solutions to the overall research problem. Potential user opinions on the utility of such a system have been canvassed and these will be presented elsewhere. Here, we have highlighted the issues which are foreseen as particular challenges to be overcome. Whether the user opinions simply concur with these or add yet further significant issues which need to be addressed is an issue for the future.

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