Interactive flashlights in special needs education

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Abstract

Flashlight torches are cheap, robust, familiar and fun and so make interesting devices upon which to base interaction technologies. Computer vision software has been developed that can recognise and distinguish between different flashlight beams and these can be used to activate digital media including audio, video or special effects. The technology appears to 'magically bring to life' objects and areas of the environment merely by shining a torch on them and has been used successfully to enhance visitor attractions such as museum exhibits and displays. This paper considers the potential for using this technology in special needs education, providing a means for children to explore their immediate environment and discover something new. Potential applications for supporting learning are proposed and a feasibility study is presented. Three case examples were conducted to assess the practicalities of configuring interactive learning experiences within the school environment and pupil's responses to the technology.

Keywords: flashlights, multimedia interaction device, learning disabilities, interactive learning space

1. The *Enlighten* interactive flashlights system

Flashlights are excellent tools for exploration and discovery, particularly in darkened environments, and the pools of light they cast focus attention and provide immediate topics for discussion. They are readily available in a variety of physical forms (sizes, shapes weights, powers and designs) and mountings (including handheld, head-mounted, stand mounted and vehicle mounted). They are also relatively safe, in terms of being shone into eyes and onto delicate surfaces.

Enlighten is a novel interaction system that uses ordinary flashlight torches to explore and interact with displays and objects in the environment. The user simply shines an ordinary torch over the surface of interest. When the torch beam is positioned over one of a set of pre-defined targets, the system recognises the flashlight and triggers the appropriate system response (Benford et al. 2004). Responses can include any computer-driven effect such as playing an audio recording or video sequence, switching on a machine or triggering a special effect.

Figure 1 Equipment required

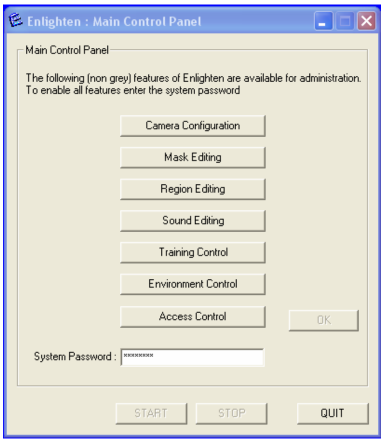

Figure 2 Main control panel

Figure 3 Assigning audio files to target zones

A key advantage of the system is that there is nothing special about the flashlights or the interaction surface used and there is no need to attach any sensors, transmitters or other devices to the surface. Enlighten uses computer vision techniques to identify and respond to different flashlight beams. This means that the system is portable and can be positioned in almost any environment. All that is needed is a standard desktop PC or laptop, Enlighten software, a standard web-cam and suitable flashlight torches (Figure 1). Use of standard equipment ensures that the system is affordable and readily available. The main constraint that affects

Enlighten is lighting. The computer vision techniques underpinning Enlighten require the local illumination to be fixed, or vary only slowly. The technology may not be suitable for some environments, which have very bright or highly variable lighting. Enlighten also requires space to mount video cameras so that they can get a sufficiently wide and interrupted view of the surface of interest.

To date, the most common use of Enlighten has been to trigger audio responses, and the current version of the software reflects this. Enlighten consists of two key components: a configuration system for interactively defining targets and flashlight torches and associating them with sound files, and a run-time system that detects and tracks flashlight beams and triggers the appropriate sound file whenever one hits a target. Configuration begins once the camera is in position. A familiar and simple graphical user interface is used to set up configuration of an interactive experience. The main control panel allows access to different modes of configuration including camera selection, target creation, sound selection and torch training (Figure 2).

A user can create target zones in the visual scene by simply 'drawing' boxes over image that the camera sees. These target zones can be repositioned, resized or removed using standard cursor click and drag techniques. In sound selection mode, the user clicks on a target zone to open the 'sound selector' window specific to that target zone (Figure 3). Sound files can then be attached to the target zone using standard drop-down menus. Once the targets are defined, the system is trained to recognise the torches to be used. The user simply plays each torch in turn over the surface while Enlighten extracts and stores a description of up to 10 different torch beams. Torch 1 is used to activate sound 1 assigned to each target, with subsequent torches activating subsequent sounds/audio files accordingly.

Figure 4 shows a pair of torches being used to interact with a poster showing the planets of our solar system (Green et al. 2004).

Figure 5 shows the two flashlight beams extracted from the image sequence. Enlighten detects, describes and recognises the individual torch beams (labelled as Class 0 and Class 2). In this demonstration system torch 0 triggers children's spoken descriptions of the planets, while torch 1 triggers samples from Holzt's Planets Suite.

Figure 4 Two-torch interaction

Figure 5 Torch recognition

Key features of Enlighten are that it:

- Is easy to use: Enlighten is very easy to learn and simple to use
- Is child friendly: Flashlights are especially appealing to children
- Is entertaining: Enlighten creates magical experiences in which everyday flashlights bring ordinary surfaces to life
- Is personalised: Different flashlights can trigger different responses, providing personalised experiences for different users
- Supports exploration and discovery: Flashlights offer the ideal means to explore dark areas. Shine a flashlight over a surface to reveal specific features and activate multi-media explanations and information about these features
- Supports shared interaction: Several flashlights can be used together providing an interaction experience, which can be shared by groups. Different responses may be triggered by each flashlight, providing a montage of effects to be explored collaboratively

Enlighten has been installed in a variety of situations. An early version was used to allow children to interact with projected graphics within a StoryTent (Green et al. 2001, see Figure 6). In the first large-scale public trial visitors to the caves beneath Nottingham Castle used Enlighten to access audio clips describing the history behind key features of King David's Dungeon (Ghali et al. 2003, see Figure 7). Approximately 150 visitors used the system over a two-day period. Lessons learned from these installations led to technical improvements to the system, which was then used in interactive storytelling sessions with groups of 4 - 7 year old children and a professional storyteller at the 2004 Nottinghamshire Show (Reeves et al. 2006). Enlighten has recently been commercialised, and a number of installations are currently underway in the museums and heritage sector (www.visibleinteractions.com).

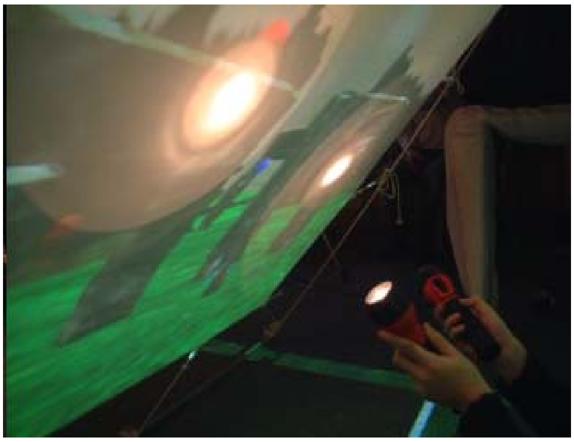

Figure 6 Enlighten in the StoryTent

Figure 7 Enlighten in Nottingham caves

2. Potential for application of the Enlighten interactive flashlights system in special needs education

The majority of our work on Enlighten has focussed on the value and properties of the flashlight as an interactive device, with particular emphasis being placed on its application in the museums and heritage sector. As a direct pointing device, it is easy to see how use of a flashlight to trigger targets located in the physical environment, could provide a stimulating activity for improvement of gross motor and hand-eye coordination skills. There is, however, an alternative view of Enlighten, which gives additional reason to believe that it may have a role to play in special needs education.

Leaving aside the use of the flashlight to indicate the physical surface(s) and object(s) involved, the core operation of Enlighten is to create associations between sections of the physical world (elements of a poster, areas of a cave wall) and pieces of digital media (audio, video, computer programs, etc). Enlightens' ability to recognise individual flashlights means that there are potentially N layers of media, where N is the number of flashlights, overlaid on the physical targets (Figure 8). The mapping between these two sets of entities may therefore be:

- One-to-one: A given target might be associated with a distinct media object, which is triggered by all the flashlights
- Many-to-one: Multiple targets might trigger the same media object
- One-to-many: Different flashlights might trigger different media from a given target

Null mapping is also possible; there may be no response associated with a particular torch/target pairing.

When exploring an interactive surface via Enlighten, users can be thought of as either exploring the physical surface, revealing digital media, or searching the space of digital media by moving their torch over a physical environment. The distinction between the two is the perspective taken by the user: are they focused on the physical or the media space? This distinction leads to two complementary ways in which Enlighten might be used to help students learn from and form links between physical objects and more abstract pieces of information:

- Interesting and motivating objects can be used to encourage students to explore the physical surface and so become exposed to digital information
- Interesting and motivating media might be used to encourage students to pay closer attention to the physical environment

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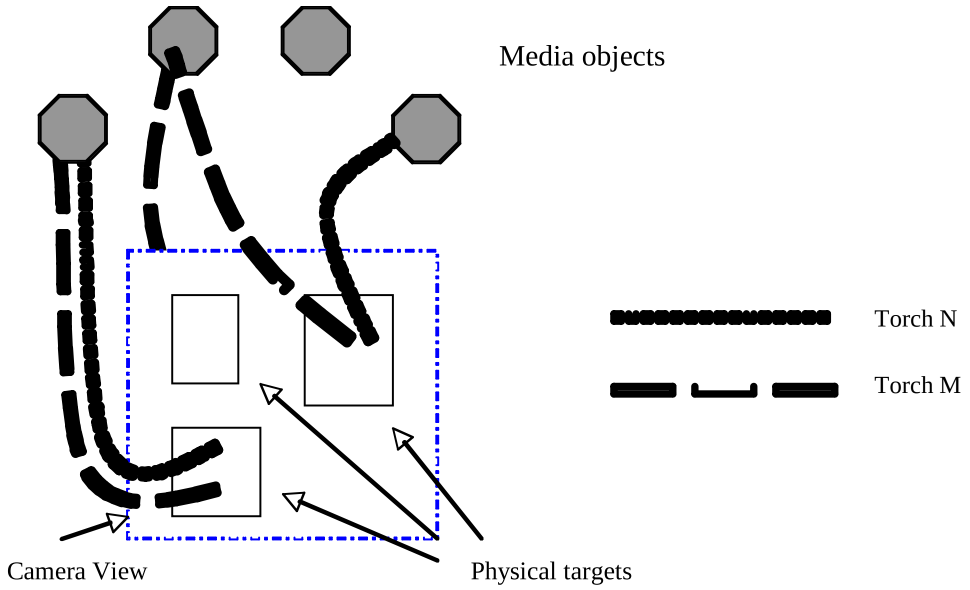

Figure 8 Mapping physical targets to media objects

The model in Figure 8 is a comparatively simple illustration of the most common use of Enlighten to date: using flashlights as a direct control interface to activate pre-recorded audio files. However, the system is more flexible than this and is also capable of varying responses over time. For example, Enlighten can be configured such that target N only responds to torch 1 after torch 2 has accessed target M. Alternatively, target K may play audio clip X the first time it is accessed by torch 3, but video clip Y thereafter.

This ability to vary response over time could be used to allow teachers to design activities in both the physical and media spaces. Physical clues could be used to encourage students to seek out rewarding media, or hints given in the media objects might lead students to seek out rewarding objects in the physical world. However, at this early stage, our research focus is at a more basic level. We are exploring potential use and utility of the Enlighten interactive flashlight system as a tool to support teachers providing special needs education. In the following sections we present teacher opinions regarding suitable ways in which the technology may be used to facilitate learning for their students, and consider practical issues surrounding set up and use of the system in a school environment.

3. Practical evaluation of using the Enlighten system in special needs education

The Enlighten system was demonstrated to teachers at the Shepherd School in Nottingham. Shepherd School is one of the largest special schools in the UK for pupils with severe and profound learning disabilities, and it has always endeavoured to use the latest innovative IT teaching strategies for its pupils. After an initial review of the system, a list of potential application uses was generated. These applications varied in terms of learning support offered to students.

Table 1 shows a list of learning skills supported by the system that may be suitable for students with different degrees of learning disability; profound and multiple learning difficulty (PMLD), severe learning difficulty (SLD) and moderate learning difficulty (MLD). It can be seen that many of the skills listed are applicable to more than one group of students. This is because of the flexibility and ease of ‘experience configuration’ offered by the Enlighten system, providing a teaching resource that can be presented in different ways. Control over what is placed in the visual scene and what digital response is to be activated is given to the ‘experience designer’, in this context, teachers. Portability of the Enlighten system also means that it can be set up in different environments, and easily moved from one location to another. Thus, teachers can construct a learning experience to suit an individual pupil’s needs or preferences. This can then be easily reconfigured to enhance learning progression or to suit the needs of a different pupil.

Whilst there is overlap of uses for students with different degrees of learning disability, it was considered that interactive flashlights would be used in different ways for pupils in each group, utilising different aspects of the Enlighten system to facilitate different types of learning.

Potential learning skills supported	PMLD	SLD	MLD
Motor control	●	●	
Visual tracking	●	●	
Hand-eye co-ordination	●	●	●
Learning cause and effect	●	●	
Control over the environment	●	●	
Memory jogger		●	●
Listening skills		●	●
Making choices		●	●
Communication		●	●
Independent learning			●
Lateral thinking skills			●

Table 1 Potential learning skills supported by the interactive flashlight system for children with different degrees of learning disability

Profound and Multiple Learning Difficulties (PMLD)
Pupils with PMLD tend to have profound learning disabilities and two or more other disabilities. These can be hearing, visual, physical and autistic spectrum disorders in many combinations. Due to their profound learning difficulties, communication is usually pre-verbal and learning skills are the very earliest level of development. The main use of interactive flashlights for these students would be to extend learning experiences offered by sensory rooms. These are currently used to enhance areas such as motivation, concentration, relaxation and visual training, although they have been used for supported learning (see Hogg et al. 2001 for a review).

Specific features of the Enlighten system for use in this context were that:

- Torch operated images within the sensory room could be easily changed (reconfigured), offering variety in terms of control over the sensory environment and responses produced. This could provide additional motivation for students to explore the environment and, potentially lead to improved interactive learning
- Torch activated sounds could provide excellent stimuli for visual tracking/scanning etc.
- Torch beams and computer activated sounds could provide extra clues in the development of understanding of cause and effect
- The torch could be used to control aspects of the environment, for example when torch is shone on a CD, the music plays

Severe Learning Difficulties (SLD)
Pupils with SLD tend to find literacy and numeric skills quite difficult. Some of them will understand basic everyday language, but may be unable to express themselves effectively.

The Enlighten system was viewed as providing an additional means for these students to communicate their choices or needs and to use this as an early stage training method for using more complex communication aids such as liberator™.

- Pupils could communicate their choices or needs by shining the torch onto photographs, objects, symbols, etc. This could be used to teach them to associate selection of an object, or symbolic representation of it, to express their desires. This activity could be enhanced by activating audio of item label (name) and sound effects representing some feature of the item (e.g. 'car' and 'sound of engine running'; 'dog' and 'barking')
- The previous configuration could also be applied to fit in with the 'Objects of Reference' scheme used throughout the school. Objects of reference are physical objects associated with an activity, such as a wooden spoon representing cookery, fixed onto cards with a text label and pictorial representation of the activity. These are used to provide a combined tangible and visual reference of planned activities for a pupil (Pease et al. 1988). Interactive flashlights could further enhance this scheme by adding audio text, triggered at different locations around the school, providing students with another cue with which to match activity with location and thus find their way to their next classroom or activity
- When the torch is shone on a book, the book could tell its story – to encourage listening skills in children who are unable to read

Moderate Learning Difficulties (MLD)
Pupils with MLD may have some basic writing skills, but they may have difficulties using these to any degree. They may find learning difficult and it may be difficult for them to access information using reading skills. It was considered that Enlighten could be used to provide these students with an additional learning method through which they can access information.

Suggested applications of Enlighten were:

- Pupils who are unable to read could shine a torch on a talking object to gain information independently
- Pupils could develop lateral thinking skills (e.g. four different torches could be shone onto one object to gain information from four different curriculum areas such as health, social, maths, science)
- Non-readers could learn to use the library by shining a torch on “speaking reference points”

4. Feasibility case studies: pupil responses to the interactive flashlight system

Potential uses of this technology for special needs education appear to be many and varied and, as with most educational tools, are limited only by the creative imagination and resources available to teachers. Successful implementation of the technology as a flexible teaching resource will be affected by the ease with which experience reconfiguration can be set up, and acceptance of the technology by students. In order to try and assess this, we conducted a feasibility study at the Shepherd School. Three learning experiences were selected from the list of ideas generated. In one day, all three learning experiences were designed, created, configured and tested. Objectives of the study were to assess:

- How easily the room could be configured to support a specific learning experience
- How easy it was to reconfigure the experience for a different purpose
- Reliability of the Enlighten system to cope with reconfiguration
- Children’s responses to the interactive flashlight system

Case study 1: Learning cause and effect
Kathleen is an 11 year-old girl with PMLD. Although she is unable to walk she can shuffle around on her bottom. She has very weak hands but can hold a spoon to feed herself with some supervision. Kathleen communicates by use of body language; she laughs when she is happy and whines when she is unhappy. Through this means she is able to show others when she wants something and when she does not want what is offered to her. It is difficult to focus Kathleen’s attention on anything. When she is in a dark room with lights on she is obsessed by an infinity box.

Objective of study:

- To introduce Kathleen to torches, to assess her ability to grasp the torch and shine it on a wall
- To observe Kathleen’s responses when a torch light is shone on objects attached to a wall

Kathleen was introduced to a lightweight torch. She grasped the torch well using a palmer grasp and she obsessively held the torch light up to her eyes whilst she looked at the full beam. With physical prompts, Kathleen could not be encouraged to shine the torch on objects on the wall. However, when an adult directed the torch beam, although not always consistent, she did make some good visual responses and she “smiled” when the torch shone on objects on the wall (Figure 9). Kathleen did not make any movement towards objects on the wall, but when the torch dropped to the floor and rolled away she moved towards it and retrieved it immediately.

Case study 2: Making choices and communicating these
Polly is a 9 year-old girl with SLD. She can walk and can hold objects. Polly has difficulties with communication and her main means of communication are by changing her facial expressions and by looking at things that she wants.

Objectives of study:

- To introduce Polly to torches, to assess her ability to hold it, track the beam and shine it on a specified place
- For Polly to shine the torch on photographs to communicate her needs

Polly held, looked at and studied the torch. Initially with help she shone the torch on the floor and visually tracked the beam. Polly needed physical prompts to help her accurately shine the torch on the photographs, and it was easier for her to control the torch if an adult first helped her to position it in the centre of the target area (Figure 10). However, on two occasions she did manage to do this herself. Polly showed understanding of the relationship between shining the torch on talking photographs of objects and being given the real object. Through this means she was able to communicate a request to be given the object she wanted (Figure 11). She smiled and showed enjoyment throughout.

Case study 3: Independent Learning
A user group consisting of four young people aged 12 - 19 years with MLD were asked to assess using the Enlighten system to obtain information about an artefact representing a subject of interest. The students could all communicate well and are able to give their opinion regarding their likes and dislikes.

Objectives of study:

- To seek students' opinions on using torches to find out information

The four young people were all able to use the torch to trigger audio information about Sumo Wrestling. A visual reference object (a Sumo body suit) was hung on the wall and when torches were shone on different areas of the body suit this would trigger audio recordings describing different aspects of the subject (Figure 12).

The students were asked in what ways they could find information. They listed; television, video, Internet, books and someone telling you. They also said that it could be difficult to find information, particularly when they had to search for it, for example, when using the internet or looking at reference books. All said that they liked using the torch but one boy said he would rather use the Internet. Two out of the four students said that they would like to do more work with the torches.

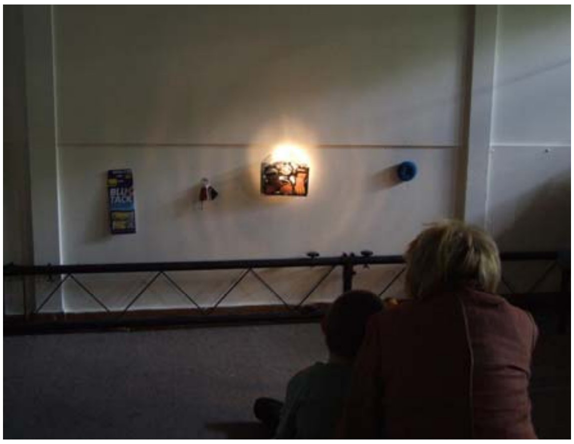

Figure 9 Cause and effect

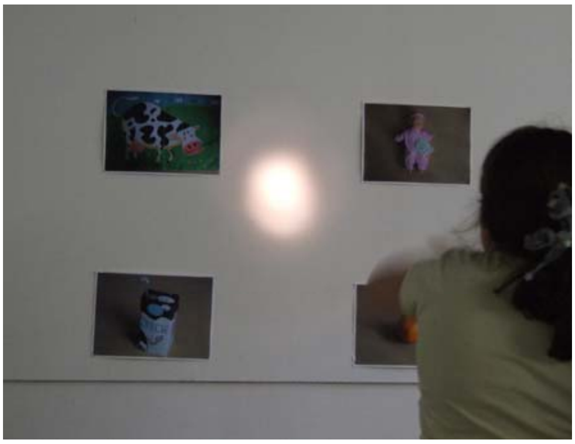

Figure 10 Controlling the torch

Figure 11 Communication

Figure 12 Finding information

5. Conclusions

Our objective was to assess potential use of the Enlighten interactive flashlight system for supporting learning in special needs education. Teacher opinion was that flashlight torches could provide a motivational tool for learning and have the potential to be used to improve visual attention in children with profound learning difficulties. For more able children, torches could be used to assist communication and provide a means for pupils who do not read to easily access learning independently. However, as a platform technology, providing a flexible resource that can be re-configured for different applications, successful implementation depends not just upon demonstrated learning outcomes, but also upon the ease with which an interactive learning experience can be set up within the school environment.

This early stage feasibility study set out to assess some of the practicalities of using Enlighten within a special needs school and also to gauge children's responses to the technology. The proposed applications required set-up of visual content, recording of audio responses, creation of target areas, assigning audio files to each target area, and training torches under different levels of ambient room illumination.

The technical trials were very successful. It was possible to create and reconfigure Enlighten for different experiences quickly (under 30 minutes including recording audio content) and the system worked reliably in both darkened room (Figure 9) and light room (Figure 11) conditions. The feasibility case studies were positive and this encouraged us. The children appeared to respond to the flashlights in different ways according to their learning needs. The pupil with PMLD was more interested in the torch itself than its effect on the environment. The pupil with SLD did recognise the relationship between the torch and the 'objects of reference' positioned on the wall and she did manage to use the torch to communicate her preferences. The students with MLD immediately recognised the relationship between the torch and triggering of targets on the object of interest. Not all of the students liked it; this may reflect their lack of interest in the subject chosen, but some students want to do more work with this technology. These students will be invited to assist with further design and development of interactive learning experiences.

The interactive flashlights system is suitable for pupils with different learning needs and/or physical capabilities. However, successful use to facilitate learning requires careful design of each interactive learning experience to suit the learning needs and interests of children. The next phase of our research is to set up trial studies to examine specific learning objectives and to see how easily teachers can create and re-configure interactive learning experiences suitable for their pupils.

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Dr Tony Pridmore is a Senior Lecturer in the School of Computer Science and IT, University of Nottingham and a member of the Mixed Reality Laboratory. He has a broad interest in and experience of image interpretation and computer vision and has published over eighty refereed articles in the field. Work to date has addressed issues in binocular stereo, the interpretation of images of mechanical drawings, the application of machine vision techniques to sewer survey, the development and deployment of vision interfaces (including visual interfaces for VR-based rehabilitation environments) and visual tracking.

Steve Benford is the Professor of Collaborative Computing at the University of Nottingham a co-founder of the Mixed Reality Laboratory (www.mrl.nott.ac.uk) and a member of the Equator project (www.equator.ac.uk). His interests include interaction design, ubiquitous computing and collaborative virtual environments. He has collaborated extensively with artists to create interactive installations and touring performances including *Desert Rain*, *Uncle Roy Al Around You* and *Can You See me Now*? He has been nominated for BAFTA awards in Interactive Art in 2000, 2002 and 2005 (twice) and was awarded a Prix Ars Electronica Golden Nica in 2003.