Inclusive wireless technology for emergency communications in the UK

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Abstract: We begin with a short review of the limitations of UK practice and government policy on wireless emergency communications. We focus on the limitations of current practice with reference to brief case studies from two recent emergencies: The Carlisle storms and flooding of January 2005, and the terrorist bombings of London's public transport on 7 July 2005. The public, including elderly and vulnerable people, were at risk as a result of two types of communications difficulties during these events, and many only received communications from rescuers on the ground. The currently available technologies for emergency communication in the UK are then analysed with respect to three dimensions:

1 whether and to what degree the technology is suitable for broadcast or point-to-point communications
2 whether the technology is based on wireless or fixed wired networks
3 the timeline requirement of the emergency, from initial alert, through emergency response communication requirements, to information and communication provision for those immediately involved and finally to the general public.

In the process, the relationship between communications networks and communications devices is considered, and both are examined for their impact on effectiveness and accessibility under emergency conditions. This is followed by a discussion of their individual potential for providing inclusive fixed and wireless emergency communications, and suggestions are made for further investigation.

Keywords: wireless technology; inclusive design; emergency communications; assistive technologies; resilience policy; multimodal interfaces.

Reference to this paper should be made as follows: Langdon, P. and Hosking, I. (2010) 'Inclusive wireless technology for emergency communications in the UK', *Int. J. Emergency Management*, Vol. 7, No. 1, pp.47–58.

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1 Introduction

In 2005 two incidents of a different character demonstrated shortfalls in resilience, particularly for communications technology that was vital to both emergency services in the immediate response and for government and follow-up facilities aiming to treat, inform, reassure and provide communications for the public at large. We focus on the emergent limitations of practice for alerting and communicating with the population; providing information and communication for the public, and in particular, examine the inclusivity of available technologies for older and disabled people. This is exemplified by the brief case studies from two emergencies: The Carlisle Storms and Flooding of January 2005, and the 7 July Terrorist Bombings of London's public transport in July 2005.

By 2020, almost half the adult population in the UK will be over 50, with the over 80's being the most rapidly growing sector. Half the adult population today is therefore aged and this trend is increasing with time with significant increases amongst the oldest age groups. This further means that there will be major impacts on individual capability in the population for the three essential areas necessary for interaction: perception, cognition and physical movement. This is consequently not a minority issue and is compounded by the introduction of new and emerging technologies. For example, the move from analogue to digital on many platforms creates technologies and devices that can be inaccessible and unusable by older age groups; the so-called digital divide (Newell and Gregor, 2002).

Despite the formation of the Civil Contingencies Directorate following major incidents, storms and other civil events, the use of communications technology during major incidents in the UK has proved to be problematic and lacking in resilience. Resilience implies that the response is not impeded or prevented by reduction, loss or damage of operational system components. In the UK emergency response organisations have been categorised as Category 1 or Category 2. Category 1 includes the immediate front line civilian services in the local area such as:

- local authorities
- government agencies: environment agency, maritime and coastguard
- emergency services: police forces, fire authorities, ambulance services
- National Health Service (NHS) bodies, such as Primary Care Trusts (PCTs).

Category 2 responders are designated organisations that will be involved in civil provision and control as the incident develops and beyond the immediate emergency response:

- utilities: electricity, gas, water and sewerage, public communications providers
- transport: network rail, train operating companies, airports, harbours, *etc.*
- government organisations: *e.g.*, health and safety executive.

Category 2 Public communications providers include organisations that provide both fixed wire and mobile services and this has implication for the provision of both alerts and post-event communications requirements. Broadcasters feature as a cornerstone of UK resilience planning and emergency planning includes the diversion of public communications networks for Category 1 and emergency usage.

1.1 The Carlisle storms and flooding of January 2005

Carlisle is in North Cumbria in the North West of the UK and is situated on the River Eden where two tributaries join the main rivers that are prone to rapid flooding. The immediate cause of the incident was a storm with high winds and more than 8 inches of rain in 36 hours. The flood mark was eventually measured at 3.5 feet above the highest previous point: an 1822 flood. The resulting breaching of defences and flooding in the city centre was unexpected and resulted in a number of Emergency Control buildings being inundated, including key Police, Fire and Ambulance Control. This resulted in a loss of Police Communication and computing resources necessary for emergency services. During the incident the electricity supply to the entire city was lost for more than 36 hours, mobile telephone cellular networks failed and land-line telephone services (including 999) were also lost. Following an emergency telephone failure plan, the Lake District Mountain Rescue Service (voluntary body) provided FM radio, base and two-way communications and communicating between Category 1 and Category 2 response services on the ground enabling and facilitating the warning and informing of the public. The remaining services capable of warning the public included the Environment Agency Automatic Voice Messaging (AVM) service for flooding. However, the AVM was an opt-in service and less than 50% of those at risk had registered with it. A second dial-in 'Floodline' telephone service run by the Environment Agency also provided broadcast information on current status for those who used it, currently less than 30% of those at risk.

In the event, the local newspapers, TV and radio services were used initially and considerable use was ultimately made of the existing internet sites that were not intended for emergency use. Many medically compromised and vulnerable people were only located and contacted by direct means such as broadcast loudhailers and rescue services' personnel knocking on doors. Elderly and vulnerable people were at risk as a result of these losses of communication at responder and alert levels and many finally only received communications from rescuers on the ground. Increased provision and Resilience of both responder communications and alert messages and information communications was clearly required and this is currently an aim of local Resilience Forums (CAR1, 2005).

1.2 7 July terrorist bombings of London's public transport

Four suicide bombs were detonated in central London on Thursday 7 July 2005 in a well-planned and coordinated attack on the London transport system during the morning rush hour. Three bombs went off just before 9 am on rapid-transit, underground (Metro) trains near Liverpool Street, Edgware Road and in tunnels between King's Cross and Russell Square underground train stations. Along with other immediate emergency responses, this resulted in the immediate shutdown of the entire London Underground network. A further explosion one hour later was on a double-decker public transport bus in Tavistock Square, central London. More than 52 people were killed and around 770 were injured. In the events that followed, two separate communication problems emerged.

Critical emergency services communication (Category 1 responders) at high medium and low levels of command (Gold, Silver and Bronze respectively) was disrupted by lack of effective communication support. In emergencies in the UK, the police are the primary command and control organisation. Their command structures in these circumstances are divided into three categories. Street-level, immediate, operational command is designated Bronze. Silver refers to station, base and emergency tactical command that may be dealing with hourly and daily events and implementing higher level commands. Finally, Gold level command refers to a separate group operating at high command level whose responsibilities are largely strategic and deliberately separated from Silver and Bronze considerations. During the 7 July bombings the high communication demands on all levels and inadequacies of provision at the time led to a Category 1 need for use of the cellular phone networks. In addition, the provision of 999 emergency services, information, reassurance, and the resulting telephone traffic had a huge impact on conventional communications, particularly with respect to Government and Category 2 responders. For example, there were over one billion hits on BBC news in one day, leading to an around four gigabytes per second information demand.[1] Interoperability failures emerged between the diverse emergency services' radio networks, most of which were reliant on analogue radio communications. A key element of the incident proved to be the failure of links to underground communications for emergencies in underground tunnels, a situation that has since been resolved by the increase in interoperability provided by the Airwave TETRA secure radio network (Airwave, 2009).

Because of the demand, an overload of fixed and mobile telephone capability occurred. Category 1 responders such as the emergency services' use of civilian GSM mobile phone networks was impaired by overload due to traffic from concerned relatives, *etc.* This was mitigated by the use of Access Overload Control (ACCOLC) invoked by the Gold Command and implemented by the mobile phone companies who provided a restricted network to registered SIMs for emergency services at the expense of (blocking) civilian use. This system has since been superseded by Mobile Telecommunication Privileged Access Scheme (MTPAS) that prioritises SIMs that are graded as privileged users but still allows others lower priority access.

The resulting primary communications methods utilised in these two events were: direct broadcast by face-to-face or amplified speech; that is to say, shouting in properties in the streets and speaking through loud-hailers; visible message boards in public areas; and local and national radio broadcasts. There were no dedicated web or wireless communications used, while mobile phone networks were co-opted to provide support to

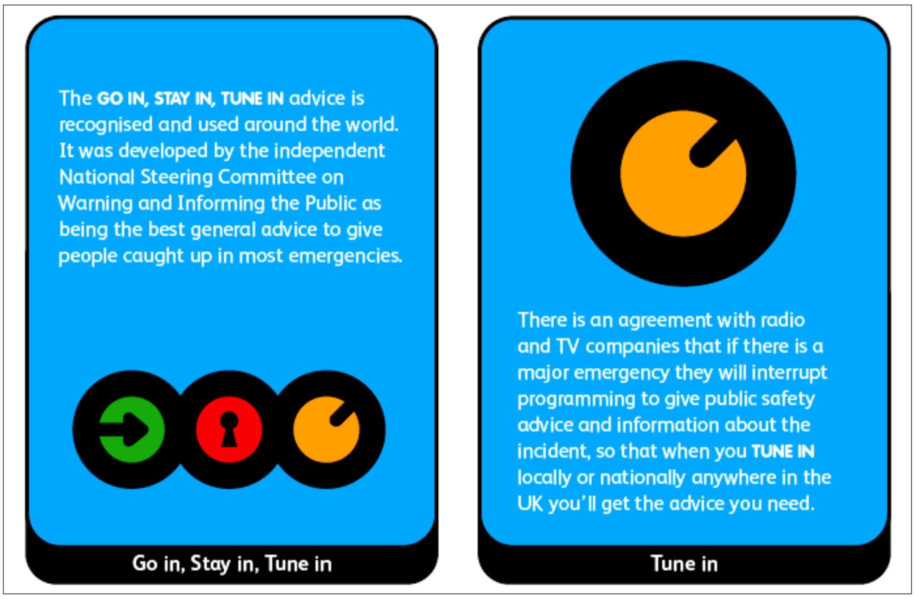
Categories 1 and 2 responders. This meant that a restricted service was available to the public due to weight of calls and as a result of switching capacity to emergency services (London Assembly 7th July Review Committee, 2006).[1]

1.3 UK government policy on wireless emergency communications – Post 2005

However, due to these and other events, such as further flooding in 2007, extensive revision and development of policy has been made by Civil Contingencies Secretariat (CCS) under Cabinet Office (UK Government) control (London Assembly 7th July Review Committee, 2007).[2] The lessons learnt from events such as Carlisle have led to a number of communication provisions designed essentially to improve emergency and immediate response and provide more resilient incident management for all involved services. For example, new provision for emergency response support includes the High Integrity Telecommunications System (HITS) and National Resilience Extranet (NRE). Based on lessons learnt from failure to support emergency command during incidents worldwide, the HITS system replaces older provisions for Gold (High command) level communications. It is based on a portable mobile Satellite communications using the UK military Skynet system in conjunction with resilient terrestrial connections. Furthermore, the National Resilience Extranet (NRE) provides a cheap but secure software tool implemented over the public internet. It provides collaborative work packages integrated with emergency Information Management (ATLAS AIMS) providing for Event Logging, Situation Reports, Message Logs, *etc.* It also offers an integrated Geographic Information System (ATLAS OPS).

With respect to public alerts and communications the subsequently revised UK Resilience body now publishes a document that makes specific recommendations for information and alerts that follows the UK's basic policy of dependence on broadcast radio and TV with the 'Go in, Stay in, Tune in' message.

Figure 1 UK DIRECTGOV Preparing for Emergencies Document (2009) (see online version for colours)



2 Available technologies

For this purpose a distinction can be made between communication networks and systems and the design and implementation of communication devices themselves. While it is clear that communication systems such as broadcast TV and radio (both analogue and digital) are currently device independent, it is also true that the functionality of such devices is dependent on the underlying technology and service offerings. Hence, older analogue and common broadcast systems do not allow interactive functionality with the user but this is now becoming possible through the use of combined internet connected TV and Set Top Box devices and services. Similarly, many communication networks such as radio cellular systems (*e.g.*, GSM, TETRA and 3G) can support interactive technology through connectivity with multimodal interfaces but product and service offerings have constrained mobile functionality in the past to monochrome text displays, key and keypad input and voice and Short Message Service (SMS) communication. New generations of devices and services are now becoming cheaply available that will support fully programmable colour graphic user interfaces, picture messaging, internet connectivity and browsing, speech input and control, real-time video links, stylus and keyboard interaction and so on. These facilities will also be more available on less mainstream systems such as satellite and TETRA secure communication networks that are available to Category 1 emergency providers.

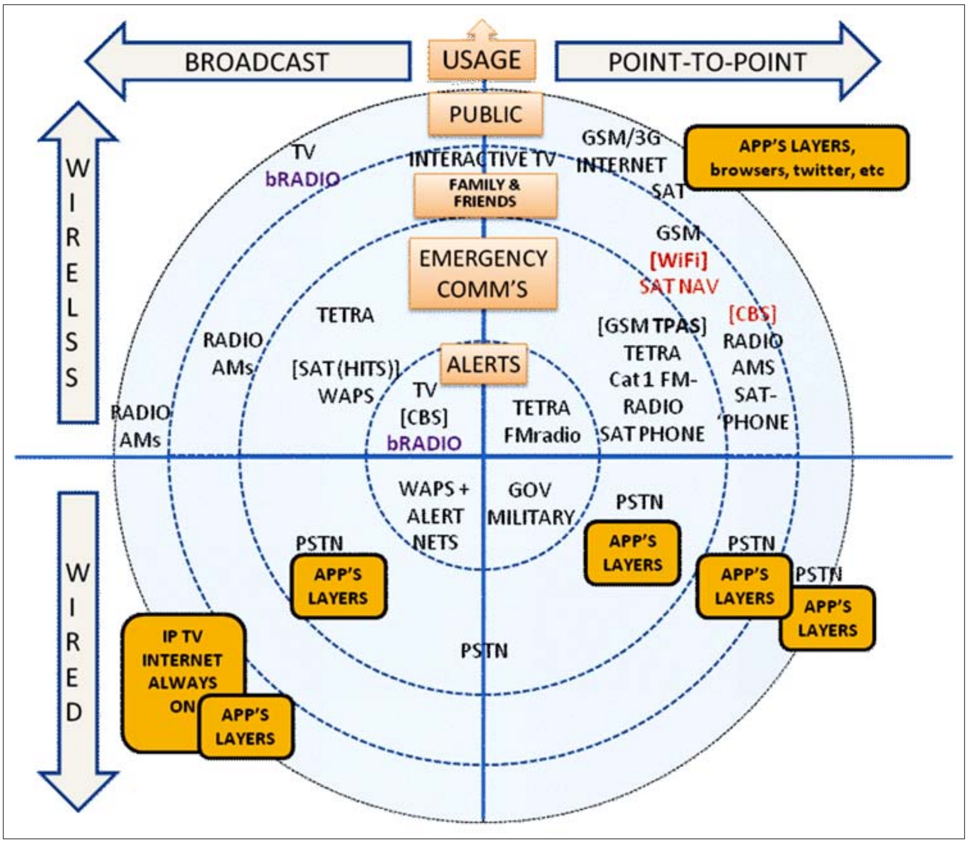
2.1 Potential of communication networks for inclusion

The currently available technologies for emergency communication in the UK were examined in the light of these considerations with particular focus on three dimensions:

1. whether and to what degree the technology is suitable to broadcast or point-to-point communications
2. whether the technology is based on wireless or fixed wired networks
3. the timeline requirement of the emergency, from initial alert, through emergency response communication requirements to information and communication provision for those immediately involved and the public.

The analysis (Figure 2) shows the positioning of most available communication technologies and associated devices but suggests that the situation is far from straight-forward. For example, although traditional broadcast media can provide alert services, they do not facilitate communication amongst emergency responders or family, friends and concerned relatives. Also, browser-based internet capability can be available on both fixed and wireless communication networks, and are capable of broadcast and two-way communications. Although both traditional wired and internet based technologies are vulnerable to power outages, modern mobile technologies may make the impact of this less significant and usage in emergencies more resilient. Certainly, a number of highly resilient technologies (HITS, TETRA/Airwave) have been consolidated for Category 1 responders since 2005 that will reduce demand on public communications networks. In particular, combinations of technologies can yield powerful capabilities for emergency communications, as when Broadcast TV is combined with internet connections to create interactive TV or when GSM/3G imaging is connected with broadcast media such as free-to-air TV allowing the public to view developing events live or shortly after they actually occur. A number of new or unused technologies and services can be identified that have potential for the provision of inclusive alerting and communication (Baker and Moon, 2008).

Figure 2 An analysis of communication technologies for their potential to support emergency communications (see online version for colours)



2.2 *Potential of communication devices for inclusion*

Inclusive design is a form of User-centred Design that aims to improve Product Design and User Interface Interaction for everyone, including the older generation and the perceptually, cognitively and physically impaired. In the context of continued demographic changes leading to a greater number of older people, inclusive design research strives to relate the capabilities of the population to the design of products by more effectively characterising the user. Recent research into inclusive design has investigated the relationship between specific functional capabilities of the population at large, derived from statistical data sets and the properties of the design features of products (Vanderheiden and Vanderheiden, 1992; Keates and Clarkson, 2004; Persad *et al.*, 2006). Products that meet the ideals of inclusive design aim to minimise the number of individuals in the target populations that are excluded from using something, or to control exclusion by manipulation of product features (Nicolle and Abascal, 2001; Coleman, 2001). It is defined by the British Standards Institute as follows (BS 7000-6:2005)[3]:

> "The design of mainstream products and/or services that are accessible to, and usable by, people with the widest range of abilities within the widest range of situations without the need for special adaptation or design."

2.3 Inclusive design, accessibility and the digital divide

An inclusive approach to accessibility therefore specifies a holistic view of the user and the interaction with human capabilities that is described at the level of perceptual, cognitive and physical dimensions and their interaction with the demands made by specific product features. This is consistent with a multimodal approach to interaction that exploits various modalities (hearing, vision, touch) and their combination in interaction to maximise inclusion. A characteristic feature of inclusive design is that it encourages a thorough analysis and consideration of multiple impairments and of variations in impairment in all sensory modalities. Hence, although conventional approaches to accessibility include larger text sizes, visual impairment may affect contrast sensitivity, regions of usable visual field, colour and motion perception (Persad *et al.*, 2006). For example, an inclusive approach considers the visual, hearing and touch perceptual capabilities of users together and attempts to quantify capability variation. This approach is well suited to multimodal interface design where capability impairment in one modality may be compensated for by using other modalities (hearing impaired may use visual captioning, avatars and sign language) or where multiple impairments can be addressed using the performance gains arising from multimodal interfaces (gesture, sound and face recognition for input can be used with sound, touch and graphical displays to enhanced effect); tangible interfaces combine input and output in an integrated object interaction where data objects are directly and immediately manipulated , as in touch tables. An interesting example of this approach is evident in the Tangible-Disaster Simulation System developed by MIT labs as a GIS tool for disaster management which uses active information pucks on a geographical display to create a direct interaction with enhanced functionality (Kobayashi *et al.*, 2006).

Sound input in the form of speech may be combined with speech input and natural language understanding programs and this can be enhanced by sound and haptic feedback or the use of conventional input technologies such as keypads. Finally, visual processing can perform face and gesture recognition on the part of the user and avatars can generate sign language, facial expressions and lip movement.

Table 1 illustrates that a large number of new multimodal options are currently available and that many of these could be exploited to support impairment and impairment combinations in novel and unique ways to support a variety of message formats. For example Avatars can be used to support visual, hearing and gestural output in conjunction with sound, gesture and haptic input (GUIDE, 2009). A related question is: what level of interaction can be supported by what technologies?

Table 1 Multimodal input and output technologies

Multimodality capability: input	
Visual	Vision analytic: gesture, face recognition, tangible (graspable interfaces), eye-gaze, gestures
Sound	Voice input
Haptic	Mouse, trackballs, touch pads, joysticks, touch gestures, tangibles (graspable interfaces)
Multimodality capability: output	
Visual	Displays (text and picture), signing as captioning, video, avatars
Sound	Speech output, screen readers, text-to-speech, directional sound (stereo), multiphase sound (signal-noise separation by phase change), tangibles (graspable interfaces)
Haptic	Force-feedback, vibration feedback, touch arrays (Braille and haptic simulations), vibration (button press simulators)
BNCI	None (Brain Neural Computer Interaction)

3 Discussion and conclusions

There has clearly been a need for an integrated approach to the use of resilient and non-resilient (public) communication methods. High resilience, mobile communication networks and devices using satellite and secure radio networks such as TETRA have now been implemented and are currently best suited for Category 1 emergency response purposes, allowing greater civilian access to mobile technology during emergencies. This is critical for the Category 2 response to major incidents, such as the need for provision of help and information about family and friends to the public. Systems such as the TPAS (Mobile Telecommunication Privileged Access Scheme) further allow Categories 1 and 2 responders to use GSM cellular phones without affecting the networks capability to respond to 999 calls or larger volumes of traffic. In addition, emergency coordination, interoperability and planning at Gold, Silver and Bronze levels will be greatly improved as a result of the introduction of new networks, systems and devices throughout the UK emergency services and this will aid communication with the public and management of major incidents. The analysis also suggests the possibility of raising awareness of ‘emergency aware’ intelligent use of networks to avoid overload. For example users can be encouraged to use SMS not voice calls and broadcast means can be used to disseminate this sort of information during emergencies by giving advice and guidance on use.

This analysis of the potential inclusivity of communication networks and communications device provides the means for assessing the most effective combinations of both to increase the accessibility of communications during emergencies. This may help to allocate priorities in developing these technologies for the provision of emergency alerts, information and instructions to elderly and vulnerable during the course of incidents. The requirement is both for one-to-one communications, for example 911/999 calls and help lines, and for one-to-many communications, such as those provided by TV, radio and GSM/3G cell broadcast.

The effectiveness of communications technologies for informing and alerting the public during emergencies is partly dependent of their inherent capability to resist disruption due to loss of power, extreme weather and other catastrophic events (resilience) as well as the configurability of cheaply available devices that are usable by ageing or vulnerable individuals with perceptual, cognitive or physical capability impairments. Traditional broadcast networks can provide alert services and information or instruction updates but do not in themselves facilitate communication networks amongst emergency responders or communication between individuals and their family, friends and concerned relatives. Wireless technology is not completely dependent on land line technology and internet capability can be available on both fixed and wireless networks, capable of broadcast and two-way communications.

Modern mobile devices provide both a challenge and an opportunity. Programmable mobile technologies may prove to be increasingly resilient in emergencies and clearly provide a more accessible platform for inclusive interfaces. Multimodal interactions are ultimately most configurable for different accessibility requirements and programmable and semi-programmable devices are best suited for this purpose, although some proprietary devices may be usable if manufacturers were involved in advance. Some technologies have not been explored such as SatNav/GSM combinations and GSM Cellular Broadcast Services.

Not all technologies are suitable for inclusive, multimodal or accessible communications in emergencies. Completely programmable devices, whose interfaces and input/output modes are configurable, are most flexible for the demands of accessibility. These include home Phones, Mobile Phones, Smart devices, Set-Top Boxes (STBs), Computers such as PCs, Laptops and Portable Digital Assistants (PDAs). Another class of devices provides programmable interfaces that can be configured and upgraded by the manufacturer. These consumer specific devices include TVs, STBs and radio receivers. A range of technologies can only be programmed by the manufacturer from the outset. Such proprietary devices include voice, messaging and data systems, *e.g.*, Pagers, Emergency Alerts, Fire alarms. There are a number of existing communication services already in existence that could be utilised for emergency communications. In particular Radio Data Systems can interrupt radio broadcasts in homes and vehicles, automatically switch to an information message (currently information such as traffic congestion) and have the potential to carry emergency warnings and information.

Manufacturers and their partners' software programming can alter the nature of existing systems interfaces and content to suit impairment; as with variation in font size, volume of sound, layout of display, and response to input devices. They could also implement advanced multimodal interfaces. Semi-programmable devices such as those used for example in Satellite Navigation systems, could introduce accessible elements and furthermore combine them with GSM broadcast media. Non-programmable technologies can be used for alerts, within the limitations of their pre-existing and fixed accessibility, as with devices using small, low-contrast and fixed font sizes, complex menus and small inaccessible controls. The extent to which partially programmable and non-reprogrammable devices can be used as accessible emergency warning systems may in part be dependent on their underlying communication system or network. For example, although analogue fixed wire broadcast networks or wide-area pager systems may be available now, their associated devices may not be currently sufficiently accessible for mainstream usage. Conversely, highly programmable devices that are dependent on digital communication networks may have great potential for inclusive emergency alerts and communication but cannot be realised in reality for some years to come due to the inherent lead times in development and marketing of their associated technologies.

In any event, the comparative effectiveness and accessibility of all these technologies under emergency conditions requires systematic experimental examination. Opportunities for their use should then be exemplified by case studies in order to assess their individual potential for providing inclusive and accessible emergency communication.

Acknowledgements

This research was funded by the UK Engineering and Physical Sciences Research Council under the Inclusive Design 3 and KT-EQUAL projects.

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Notes

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