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USABILITY CONSIDERATIONS IN THE DESIGN OF HANDHELD ELECTRONIC DEVICES

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Abstract

Many handheld electronic devices such as cellular phones, personal digital assistants (PDAs) and TV/video remote controls have become a part our daily life; and in recent years there has been competition amongst manufacturers to introduce increasingly compact forms of these products. Consequently, their sizes are decreasing gradually to palm size or smaller and the user-interface is becoming more difficult to interact with. Many of these products are not accessible to large sections of the population because the diversity in user capabilities and requirements was not accounted for during the design process. One reason for this is the lack of proper design guidelines to take account of the needs and expectations of a wider range of users. This paper focuses on the necessity of adopting inclusive design approaches in the design of handheld devices, describes some important design issues pertinent to these devices in *general* and finally aims to give a broad range of solutions that the designers can apply in a wide variety of circumstances when designing handheld electronic devices.

Keywords: handheld devices, ergonomics, human factor, man-machine interface

1. Introduction

We have moved into a new era where products that were once fixed and installed at homes or in offices in the past, have now become portable. Advances in wireless technology [1] have made making phone calls, sending emails or accessing the internet possible from anywhere at anytime, even on the move. A WAP (Wireless Application Protocol) enabled mobile telephone can be considered as an example. Unfortunately, many of these products are difficult or impossible to use by older and disabled people [2] because their needs were not considered explicitly during the design process. This may be because the designers are unaware of the needs of users with different capabilities and design instinctively for someone with physical and skill capabilities similar to their own, or do not know how to accommodate their needs into the design of the product [3]. This paper attempts to create awareness among the designers about the necessity and benefits of considering usability criteria during the design of handheld devices. It also gives guidance on incorporating these criteria into design.

2. Why should handheld devices be designed inclusively?

Many handheld devices are extensively used by almost everyone. For many people, these devices have become basic necessities in their everyday lives, without which their lives would become more difficult. There are two principal reasons why the needs of elderly and disabled

people should be considered in the design of handheld devices. One is based on potential market of the elderly and disabled people and the second is based on the legal imperatives.

2.1 World population demography

The world's population is growing older and older. According to WHO information, by the year 2020, there will be more than 1000 million people over 60 years old [4]. Europe has the highest proportion of elderly people, comprising 20% of its current population and rising to 25% by the year 2020 [4]. The average age in many countries is increasing. These older people have significant disposable income [5] and will be looking for quality products and services that will help them continue to live independently [2]. Ageing is also associated with loss of capabilities and increasing impairments and increases functional limitations. Many impairments such as reduced hearing and vision are often degenerative in nature and increase with age [6]. For example, 88% visually impaired people are over 60 years old and over half of visually impaired people in UK live alone [2]. Disability may or may not be age-related and can affect young people as well. Therefore, older and disabled people constitute a significantly large group of customers and their needs and expectations should not be overlooked.

2.2 Imposed legislation

In recent years, there have been increasing laws and regulations that require companies to make products that are usable by people with disabilities [6]. For example, the UK Disability Discrimination Act [5] and the American with Disabilities Act [5] prohibit discrimination on the grounds of disability and require companies to create products or services that are accessible to all. These legal imperatives, what may be called "push" legislation [5], force companies to incorporate the needs of disabled and elderly into their design processes. There are many government programmes, what may be called "pull", that provide industries with incentives to make their products accessible to the elderly and people with disabilities. Thus, it is essential for industries to respond to the needs of these people.

It has been realised that many handheld devices exclude a wide range of users and that a slight modification or change in the design could include large numbers of those users. The cost of such changes should be negligible if made during the initial design phase. Therefore, it can be suggested that the major advantages of considering usability criteria in the design of handheld devices are:

- improvements in user performance and usability of the product;
- making the product distinctive in the market place;
- preventing losses from legal actions and legislation;
- reducing the need for subsequent re-design.

3. Strategy- usability approach

3.1 Understanding the term 'usability'

Different academics, professionals, designers and end-users define usability in various ways. Nielsen (1993) describes usability as a part of system acceptability (utility, usability, cost, safety, reliability, etc.). He urges that usability applies to all aspects of a product or a system with which users might interact [7]. The word 'usability' itself has two segments: 'use' and

'ability'. Thus one way of describing it would be to say that it is a quality of a product that has been designed and manufactured taking into account the abilities and capabilities of the end-users. There is a misconception among designers that a system or product suitable for use by an average user is a good design [8]. The term 'average user' is vague. For example, a handheld device designed for the average hand size would exclude many people whose hand size is significantly smaller than average. However, if the designer designs the device for the smallest hand, it will include those users. Thus, for a good design, the diversity of the user capabilities must be considered.

3.2 Understanding the 'usability gap'

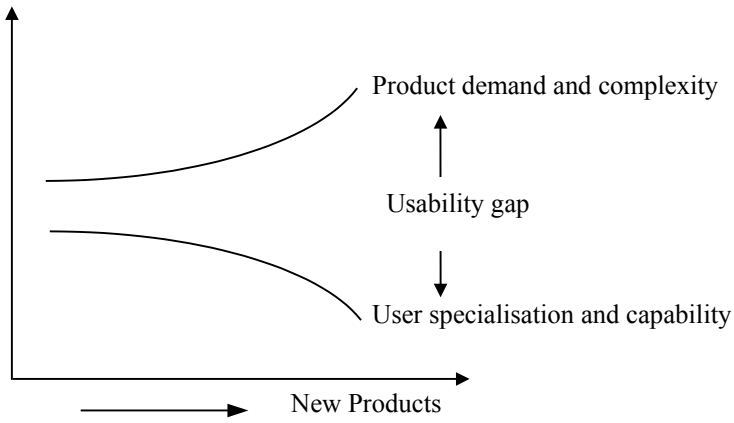

Figure 1. Usability gap (after [9])

In recent years, more and more sophisticated and complex handheld products have been introduced into the market. This is especially true for communication devices. In the past, these devices were available to a very limited group of people who used to be trained in their use [9], but now, due to the low cost of technology, they are available to all. However whether these devices are accessible to all, is still unanswered. While the complexity and product demand (minimum user capability required to use the product) are increasing tremendously with newly emerging products, the user specialisation in these products is concurrently decreasing. This mismatch has created a large usability gap [9], as shown in Figure 1.

3.3 Reducing the 'usability gap'

Thus, it is clear from Figure 1 that to reduce the usability gap either user capabilities and specialisation have to be increased or the product demands have to be lowered. From a design point of view, increasing user capabilities is unlikely to be a viable option. Thus, it is necessary that the user interface be made easier for varying user capabilities. The products should be designed such that their requirement for user specialisation and capabilities is minimal. However, due to large variation in user characteristics, their capabilities and impairments, situational demands and technologies, it is unlikely that a single product would fulfil all of the requirements for all users. Therefore, a combined approach of both 'Inclusive Design' and 'Assistive Technology' will help reduce the usability gap [10] as shown in Figure 2. Inclusive Design Approach, a relatively new approach, argues that designers should ensure that the products address the needs of the widest possible audience. Inclusive Design basically aims to minimise unnecessary exclusions of end-users. Assistive technology on the other hand provides means for people to use products more effectively.

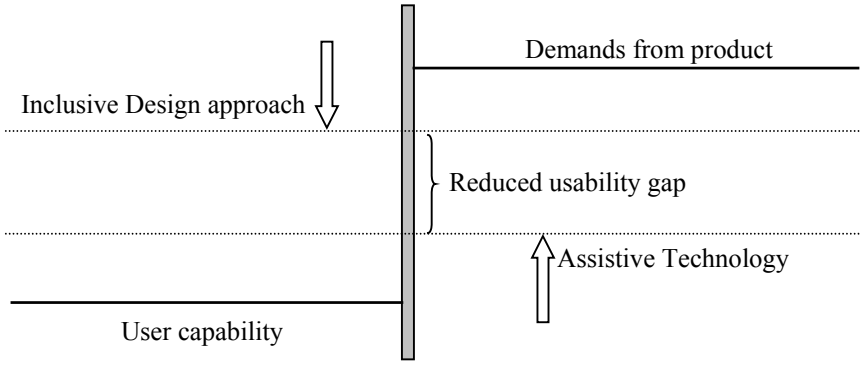

Figure 2. Inclusive Design and Assistive Technology reduce the usability gap (after [10])

4. Aims and methodology

4.1 Aims

The objective of this research was to find the best possible ways to make handheld devices more usable such that a wider range of users could use them with ease. Almost daily different forms of handheld devices are being introduced onto the market and each of them performs different types of functions, such as phone, e-mail, calculator, notepad, etc. Also, market trends are changing rapidly and people are tending to buy a single portable device for multi-purpose use. For example, in the past people used to have separate calculators, telephones, diaries and PCs, but now they want to have a single portable device that can perform all of these tasks. Therefore, the term 'handheld device' in this paper is meant by a device in general that can be carried and operated by hand.

4.2 Usability decomposition of a handheld device

Handheld devices vary in their attributes such as shape and size, applications, technologies and contexts of use. However, there are many things in common in their user interface. In general, almost all handheld electronic devices comprise a *physical body structure*, a *keypad* and a *visual display unit* as shown in Figure 3. These are the three basic features which constitute the central domain of the user interface.

The physical body structure: A user-friendly design of the overall configuration of a device is obviously a key factor in its success. The device's overall geometry, shape, size, weight, stability, grip, etc. are crucial for people with disabilities and impairments such as reduced strength, tremor, etc.

The keypad: The basic means of access to any handheld electronic device is the keypad. Even though new solutions, such as screen-based windows (touch-screen) and speech recognition, are appearing, keypads will probably remain the basic means of access for a long time [2]. It is important, therefore, that keypads are designed to be easy to use for most people including the elderly and disabled. This will also improve the overall usability of the device.

The visual display unit: The display units range from small to large size, alphanumeric to full graphic display, and monochrome to colour displays. There are many technologies available in the field of display and many new ones are emerging day by day. However, it has been recognised that liquid crystal displays (LCDs) are more popular among notebooks, mobile phones, pagers, PDAs, and other portable electronic devices.

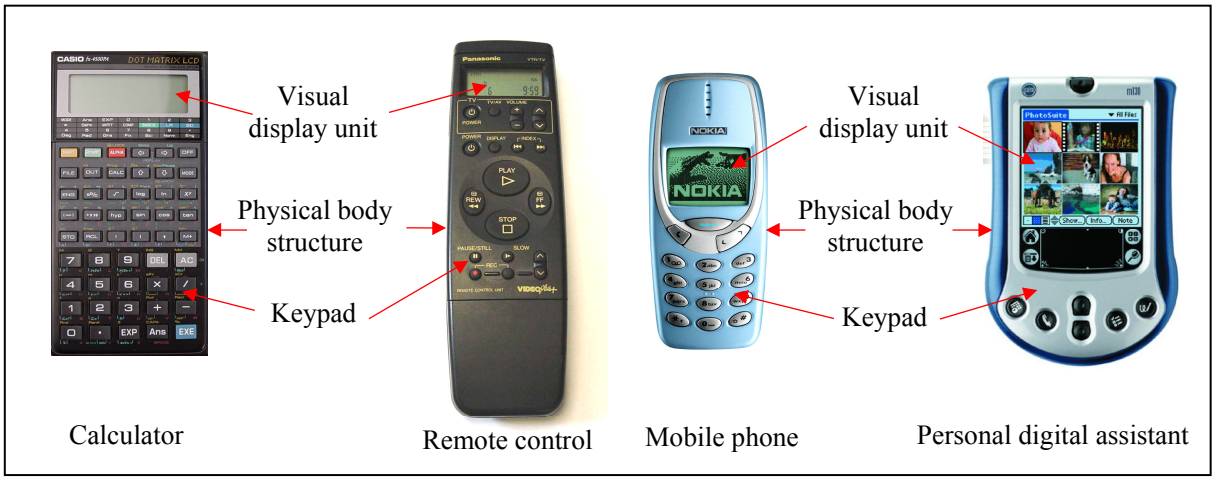

Figure 3. Three common features: physical body structure, keypad and visual display unit

As electronic products are getting smaller, their displays are also forced to be smaller due to the limited space, making them increasingly more difficult to read. The visual display unit serves many purposes of the device, e.g., display menus, visual feedback, etc., but if it is not designed keeping users with poor vision in mind, it will exclude significant portions of the market. The size alone does not affect the accessibility of the display unit, but many other aspects of the display unit can be considered to make it more accessible. Some of these aspects are described in Figure 4.

Good interface design of these three features determines the overall usability of a handheld device. This research is concerned primarily with the in-depth study of usability of these features and provides several useful recommendations that would help designers in designing these features in many handheld devices. Each feature must individually be designed in a way that can be used by more and more people. Again each of these features is comprised of several attributes which the designer must consider. Therefore, the first step would be to breakdown each feature into corresponding characteristics that constitute the feature from the usability point of view. Some general characteristics of each of these features, which play principal role in usability, have been identified as shown in Figure 4.

For example, to achieve an ergonomic body structure of a handheld device, it is first necessary that all characteristics such as shape, size, weight, grip, etc. that make up its complete interface domain should be identified. These characteristics, when offering an acceptable level of accessibility, would determine the effectiveness of the device in relation to its body structure. However, it is always difficult to determine which characteristics should be considered and how their values (magnitudes or attributes) should be determined.

Each of these characteristics can also be further divided and subdivided into more detail to gain higher levels of accessibility as shown in Figure 5.

4.3 Applying usability criteria

The end-characteristics that appear at the end of the hierarchy of the product decomposition tree should then be designed keeping in mind possibly the lowest capability requirements of the product. For example, the characteristic *size* of the feature *body structure* can be further broken down into four sub characteristics: *circumference*, *width*, *thickness* and *length.*

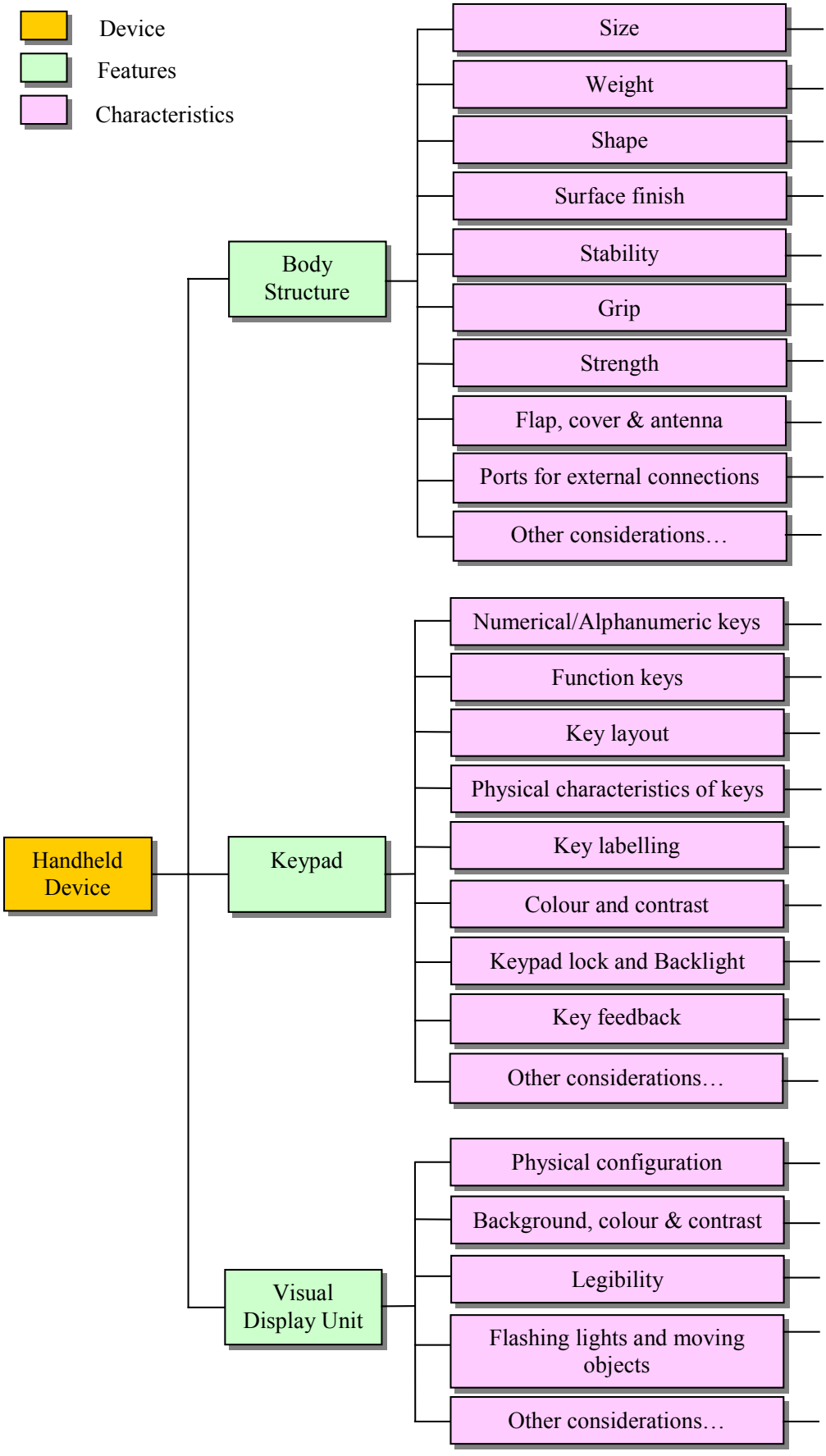

Figure 4. Breakdown of a handheld device from the usability point of view

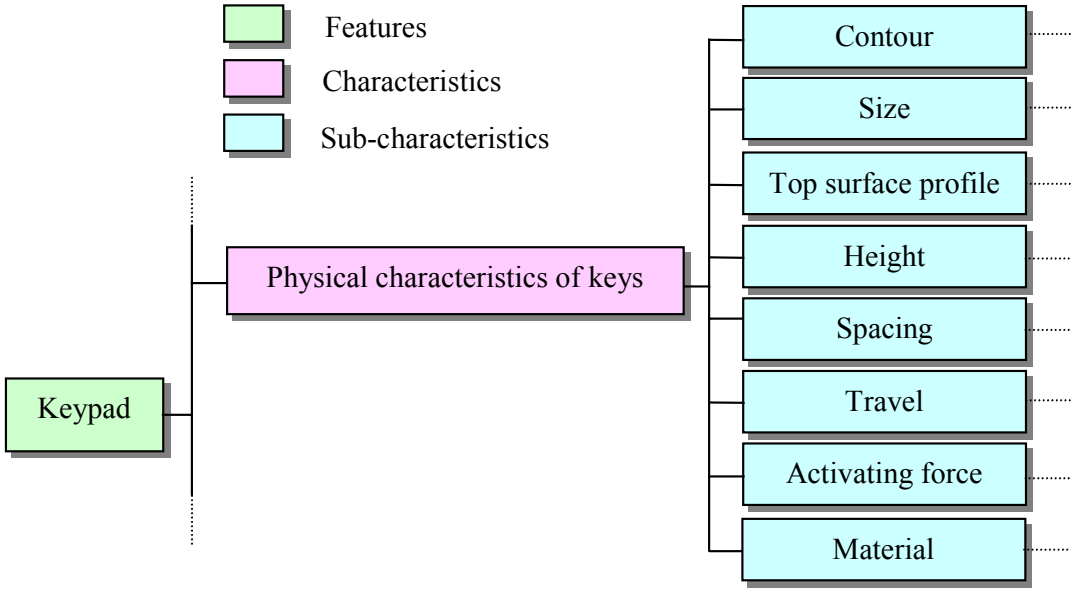

Figure 5. Example of detailed breakdown of a feature

If the designer is to determine the circumference, he/she must find out the lowest capability demand that would include as many users as possible. It is to be noted that people with weak grip have to be able to grasp handheld devices thoroughly around the circumference. Consequently, the circumference of the device should be designed such that the smallest hand can grip the device effectively. According to the anthropometric data [11], the diameter of the largest circumference of a cone that can be grasped by the smallest hand is 32.1 mm. It should be noted that the diameter considering the thumb & the middle finger (40.2 mm) is greater than that considering the thumb & the index finger (32.1 mm). Therefore, if the value 32.1 mm is chosen, then the users without or unable to use their middle finger could also be included. Thus any device, which is intended to be grasped thoroughly around the circumference, should have a circumference of about 101 mm at the most.

In making decision or assigning values to the end-characteristics, there are several other factors that designers must take into consideration. Determining the value of some of the characteristics may be straightforward, but in many cases it becomes tricky for the designer to decide the optimal solution. Any decision at this stage must justify that it ultimately is going to improve the overall accessibility of the device. Any decision should include the following points:

- Have the capabilities of different age groups and genders been considered?
- Have the needs of people with possibly all kind of disabilities been considered?
- Have the aspirations (likes and dislikes) of wide range of users been considered?
- Have the technical constraints been considered?
- Is the design reliable and durable?
- Is the design better than the prevailing designs?
- Is the design attractive enough to appeal all age of customers?
- Has the design followed the prevailing standards?
- Have the legal imperatives been strictly followed?

4.4 Constraints, contradictions and trade-off

The design decisions made for individual characteristics or sub-characteristics of a handheld device depend greatly on who the end-users are and what type of device has been considered. A very general decision may not be applicable to all situations. Also, a design prepared keeping in mind the lowest capability requirements of the products may be sub-optimal for fully able-bodied users and may not appeal those users. Also, some decisions may be restricted by technical requirements of the product. For example, the weight of a handheld device depends on its battery-weight, which depends on its storage capacity. So, the device weight cannot be reduced beyond a certain limit without affecting its utility. Similarly an antenna, which is undesirable from ergonomic aspects, cannot be avoided in some devices due to their technical constraints.

Decisions made in favour of one characteristic may contradict with the others. For example, a large-sized display unit and keypad would help visually-impaired to read legends on them more clearly, but if they are to be achieved the device would become bigger. However, users with weak hand strength require small-sized devices that can be carried and held easily. Therefore, due to diversity in end-user requirements, it is possible that a decision satisfying the requirements of one group of users may contradict the requirements of others. The designers should be aware of these. In such cases, the designers may have to 'trade-off' between two contradictory decisions and have to resolve according to the nature of the product, application and targeted users. Sometimes, it becomes necessary that additional requirements be fulfilled by external means compatible with the original device, e.g. external keyboard connecting to mobile phone through wireless technology or a cable.

There is often more than one solution to a problem. Designers should always look forward to finding as many solutions as possible to an individual end-characteristic. In many situations, it becomes essential to choose one solution instead of another that fits well with other decisions. For example, in case where the legibility of a display screen cannot be improved by making the screen size bigger, it may alternatively be improved by achieving high contrast between the legend and the background. Therefore, for each of the end-characteristics, designers should find as many options as possible and then the best solutions, which least contradict with other solutions, should be assigned to them.

5. A case study: assessment of user-friendliness

Despite the fact that designers and manufacturers have a good understanding of the growing and essential needs of user-friendly interfaces, it has been found that many products do not meet them. Two handheld devices (remote controls), as shown in Figure 6, currently available in the market were assessed for their usability and accessibility, and compared against each other for the purpose of our discussion.

Both products, compared against the characteristics regarding their *Body Structure* as described in Figure 4, have the following advantages – both are small in size (handy), light weight, strong enough to withstand potential shocks, have good stability when placed on a flat surface, and have no flap/cover or antenna. However, due to its concave shape product 2 (black) has better grip than product 1 (white). The shapes of both the products lack feature to guide the visually impaired user to hold the device correctly. Moreover, product 1 has sharp corners which are undesirable from the usability point of view.

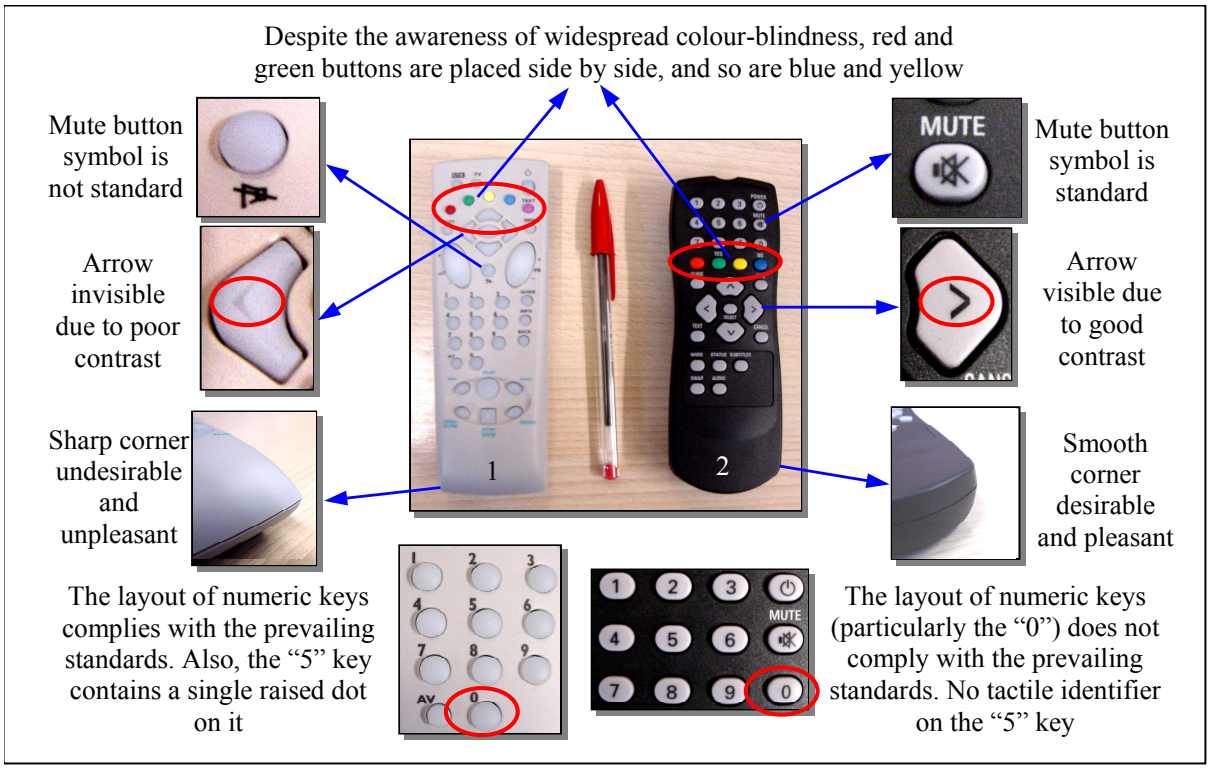

Figure 6. Comparison and assessment of user-friendliness of two standard products

With regard to the *Keypad*, the numeric keypad layout of product 1 complies with the international standards, whereas, product 2 does not – the "0" key should have been at the bottom. Also, there is no tactile identifier on the "5" key on product 2. Failure to comply with these standards makes it more difficult for visually impaired users (and also users in low-light conditions) to use the product. Product 1 also fails to use standard notation for *Mute* button. More importantly, product 1 provides very poor contrast between the white buttons on a white casing. In addition, the annotations on most of the buttons are engraved in such a way that they are almost invisible even for normal-sighted users. Although some of them have been supplemented with printed legend, the one shown in Figure 6 has no such supplement. In contrast, product 2 has very good contrast between the casing and the buttons and also between the buttons and the legends printed on them. This makes product 2 more prominent and usable. Other issues are highlighted in the Figure 6.

There are many other handheld devices, especially mobile phones, on the market which provide clear evidence that usability criteria have not been addressed during their design, to the extent that many of these products are inaccessible to a larger range of population.

6. Conclusion

Applying the principles outlined in this paper, a complete set of guidelines has been developed [2]. Useful recommendations have been made for each of the three features considering their end-characteristics comprehensively. Several alternatives have been proposed to facilitate designers in their design for specific devices. It has been first suggested to make improvements to the features themselves, however, where it has not been possible, suitable assistive technology has been proposed. Each recommendation is supplemented with examples of real existing products with photographs and illustrations where possible. The

outcomes of this research are hoped to help designers of handheld devices to create products that will be accessible to wide range of users and reduce the needs of custom products which are less cost effective as compared to standard products.

Acknowledgements

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