Heuristics in Ergonomic Design of Portable Control Devices for the Elderly

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Abstract. The prolonging life expectancy and, as a result of it, the growing number of people of elderly age means that more attention should be devoted to the design of ergonomic equipment which includes the needs of this group of customers. Elderly people often suffer due to poorly designed technical facilities, which discourages them from using equipment to improve the quality of their lives. The article summarizes the identified needs of elderly people in relation to control devices along with the general guidelines for the ergonomic design and design approaches for people with disabilities including: universal design, inclusive design, design-for-all, barrier-free design, and accessible design. Among the most important limitations of elderly people are included: reduced psychomotor and sensory efficiency and range of motion, decreased strength, and a decreased ability to remember. In this way a checklist is comprised of criteria such as anthropometric compatibility, ease of use and handling, transparency and visibility, tolerance for error, sensory substitution, and palpability and feelings. The list of identified criteria is evaluated by users resulting in a quantification of individual requirements. Based on interviews with users, an identification and classification is also made of the basic groups of control devices used by the elderly. As a result of these measures checklists are obtained to evaluate each group of the control devices, which examine the typical and commonly used devices in the Polish market. Some selected devices have also been subjected to an evaluation during arranged performance situations involving elderly persons. The information obtained during this is discussed within the article.

Keywords: ergonomic design, heuristic methods, design, ergonomics, devices for the elderly.

1 Introduction

Thanks to advances in medicine and improvement of the quality of life, its average length is constantly growing, now reaching in the EU an average level of 76.7 years

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for men and 82.6 for women. This is not the final value as it is estimated that the average life time will be extended for the next 5-9 years in the first half of the twenty-first century, and the age limit achieved by women in the future may reach values between 120 and 130 years [12]. This gas an impact, among other demographic changes, on the effect called aging. A clear effect of this trend is discernible in the Population median age index, which in 2011 amounted to 41.3 years in 27 EU countries, and over the next 40 years it is likely to reach the level of 48 [14].This means that there is a need for addressing the needs of elderly people in the designed products, services, architectural environment, and even workplaces in a better way. The products will not only have to meet the safety requirements in the currently understood criteria [15], but also take into account the cumulative aspects of user groups, which are the elderly, that are susceptible to certain factors. [7]. The ergonomic design also allows for achievement of such product parameters, which make it resistant to the occurrence of some abnormalities in the manufacturing process itself, which obtains a minimal loss of quality, with the planned cost of production [31].Thus, ergonomic approach allows to keep a balanced development in all areas of human functioning. [22] Hence, it appears that there is no alternative to ergonomic design in the context of an aging society. We need to be better prepared for a number of socio-economic changes because the current pension solutions cease to be effective, and the period of professional activity will increase significantly [6].

One of the important issues in the design for the elderly is the difficulty in defining the characteristics of the general population and an indication of their actual needs. This is due to the large variation of the design characteristics of the elderly, their low representation among decision-makers and the difficulty in obtaining data regarding their needs. This last factor arises from the fact that an aging period is a natural time when all kinds of activities are associated with an increasing effort and in a way it gives permission to exclude these users from certain groups of solutions (attempts to sanction the right age to drive a vehicle, etc.). Leaving aside the moral issues of such considerations into the safety of a group of users at the expense of an exemption of others, it should be noted that there are a number of solutions where the lack of adaptation to the needs of elderly users is not justified by any rational reason. Enabling elderly people to use modern technical equipment will ensure the maintenance of health and safety [30] and also will allow to create a proactive environment [20]. What is more, a suitable and ergonomic design of equipment for the elderly will be connected with obtaining high efficiency of the anthro-technical system [8], as well as with facilitating the implementation of useful social functions for a long time [21]. An example of a group of objects which low or high ergonomic quality may significantly affect the quality of life of elderly people are portable control devices. Appropriate adjustment of these devices to the psychomotor needs of the elderly will be crucial in their independence or self-sufficiency.

The purpose of this article is to present pilot studies undertaken by their authors to identify the ergonomic features of portable control devices for example, remote controls, and to build a model of ergonomic quality of these devices for later verification. Due to the chosen target study, the notion of the precision regarding control motion while using the device was not included. The only function that was taken into account was only the precision of the selection and activation of individual control segments.

2 Ergonomic Features of Portable Control Devices

Ergonomic design criteria for the control devices can be found in the Directive on machinery [11], which states that they should meet the following requirements: to be clearly visible and identifiable, ought to use pictograms where appropriate, positioned in such a way as to be safely operated without hesitation or loss of time and without ambiguity, designed in such a way that the movement of the control device is consistent with its effect, positioned in such a way that their operation cannot cause additional risk, designed or protected in such a way that the desired effect, where a hazard is involved, can only be achieved by a deliberate action, made in such a way as to withstand foreseeable forces; particular attention must be paid to emergency stop devices liable to be subjected to considerable forces. Under ergonomics the norm gives that under intended conditions of use, the discomfort, fatigue, physical and psychological stress faced by the operator must be reduced to the minimum possible, taking into account some ergonomic principles for example: allowing for the variability of the operator's physical dimensions, strength and stamina.

Among the identified ergonomic criteria principles one should also indicate the optimum layout of control devices due to their importance, frequency, order of use, and the grouping of functionally related equipment [28]. It is significant however how the information will be entered [18], what is the length of steering movements affecting their accuracy as described by Fitt's law [13, 16], non-visual support [29]. Devices ergonomics also should be considered in terms of compatibility, and hence the possibility to use multiple devices in the same way [25].

Ergonomics of portable control devices is not as simple as it might seem to be and the sole rules citation that are formulated by various authors is only a resulting fragment of a problem. It should be noted that the functional quality of the equipment is influenced by the quality of the realized interaction in the perceptual-motor process [9].The quality of implementing the interaction can also be described from the intangible assets point of view, and as a result it may be subject to requirements such as usability, learnability, flexibility, customizability, observability and robustness [32, 36].The design principles developed for people with disabilities are also not without significance [5].

To sum up, it can be observed that there is a large variety of sources and levels of ergonomic requirements in regard with portable control devices. It should be also noted that most of these will result in the range of functionality of the implemented remote control devices.

3 Senior Needs in Portable Control Devices Design

Studies indicate that the needs of the elderly are mainly due to perceptual deficits and the weakening of psychomotor function [38, 39]. This relationship reflects the needs of those who use portable control devices, which has been proven by the studies on Latin American community. Design suggestions from older adults included making the numbers and buttons larger and installing auto-shut off timers on remote control devices [34].

Elderly people certainly feel more discomfort associated with the need to perform forced and repetitive movements which only aggravate part of the musculoskeletal system. Slight movements performed during control operations cause the movements of the muscles in the shoulder, upper arm, forearm and index finger to be activated. Research that was made on touch screens showed that after longer periods, a significant arm fatigue occurs, what is ergonomically critical especially for older users [1].This means that the mapping of manipulative abilities requires a model of dysfunction [4] which appears at the specified user with age.

Another important factor in the process of designing portable control devices while taking into account the needs of elderly people is required strength, accuracy and speed of movement. These are the factors which affect the size of the required parameters initiating various device functions. The variation in this field results from different functionality of the elderly, as well as relations between the grip, the direction of a force and the speed of implementing steering motion [35].The authors suggest that grip strength decreases with age, but at least in the initial period of an old age rather slightly [24] greater declines are observed after the age of 70 years [41, 42]. A slip force is another analyzed parameter, which indicates the strength that is used in order to prevent an item from slipping from the hand. This force is only slightly greater than the weight of the item and in the case of the elderly it is higher than in younger people. It translates to less coordination when lifting [27], as well as the reduced level of sweating, which affects greatly the coefficient of friction. [10]. In turn, analogically, in the case of equipment initiated by voice, an input parameter will be an adequate strength and a clarity of voice. This type of signal modality is of the utmost importance for people with significant psychomotor dysfunction. However, due to the specificity of an issue as well as a significant level of error diagnosis [37] it was not included in the present model of ergonomic quality.

With age, the ability to perform multiple functions simultaneously (divisibility), the ability to remember and distinguish is declining. This usually results in reduced demand for the number of used features. [23] Thus it may be desirable to reduce unnecessary or rarely used features by hiding or inactivating them. Besides, too many functions made it difficult to distinguish the desired function from others [26].

4 Method Description

The procedure of the findings consisted in collecting the identified in literature needs of the elderly in the field of portable control devices. The needs were assigned design criteria using QFD method. This step allowed the determination of the final list of requirements. The research group was 6 people (3 women and 3 men) aged 65 to 84 years. The study uses the approach of ethnography design [40] which process was recorded using a video camera. Test procedure consisted in assessing the validity of the previously identified features of the portable control devices through the test person, who then was shown 3 universal remote controls (these can be programmed to control different devices), two of which are laid down as devices for seniors. By using these devices a subject's task was to perform 3 sequences of action:

- following the steps of battery replacement (removing previously inserted battery and inserting the new batteries),
- programming remote controls on the basis of the information contained in the user's manual instructions, (in view of the methodological difficulties of separating the issue of control from the characteristics of the manual instruction, the evaluation of this step occurred in a total way, the instructions have been translated, and then presented in a unified form),
- making an identical control sequence by using each of the remote controls.

During the process of carrying out the tasks, the tested person was not forced to keep a certain pace to perform the activities. There was not also any interference in the way the activities were performed even if it was wrong. After doing the above activities, the tested person assessed the workload when using NASA TLX devices [17], and then evaluated the fulfillment of the requirements that have been previously accepted for validity. NASA TLX scale was chosen due to the factors described in the literature such as it is more acceptable to participants [19] and it is more sensitive to mental workload differences than the second widely used method - SWAT [33]. In order to assess the validity as well as to check whether it complies with all the requirements, a 3-point scale was used, due to the fact that the tests that have been previously carried out with much smaller precision, caused confusion and the subjects chose values from the beginning, middle and end of the scale.

All the persons prior to study, filled in a questionnaire regarding their health. None of them showed an impaired hand function to a considerable or moderate degree, and the previously mentioned health problems, according to the respondents, did not affect the possibility to use the equipment.

5 Results

The features of ergonomic portable control devices, which representative can be a universal TV remote control, that are presented to evaluate older remote controls are:

1. grabability - proper shaping of the user's hand,
2. buttons availability - the ability to select key accurately,
3. ease to recognize the application of a key - distinguishability, size of the keys and their signs,
4. recognition of the device from other devices – the faciliation of device search,
5. visibility of the function regardless of the lighting conditions - backlighting,
6. resistance to the user's errors and the possibility to correct them,
7. safe use and technical maintenance of equipment,
8. appropriate weight of the device and its balancing,

9. ease of use - intuitive controlling - predictability - compliance with practice
10. the logic of a device - coherence,
11. easy cleaning of all surfaces,
12. ease of use – battery replacement,
13. mechanical resistance of a device,
14. durability of the printed symbols and text,
15. feedback – confirmation of the control element activation,
16. reduced squeeze strength of the device with your hand (appropriate level of force to the coefficient of friction),
17. reducing the forces necessary to activate the button of the device,
18. alternative service in the event of the inability to use the default hand,
19. stability to place the device on the surface when running the function by selecting keys on the resting remote control,
20. stability of buttons that are in contact with a finger,
21. ability to use the device in conditions limiting the precision of the movement such as wearing gloves.

The presented criteria constitute only some that were considered during the selection of ergonomic features of portable control devices. Their full listing would exceed the permissible volume of the article.

Prior to the experiment, according to respondents, the most important requirements for the comfort of use were the requirements of the following numbers: 3, 4, 5, 7, 10, 13, 14, 15 This means that the greatest significance were such features as: function recognition, keys visibility, logic, and durability.

This article did not present an assessment of compliance with the requirements for individual remote controls, because they proved to be correlated with actual users' sensations only to a small extent - the criterion was very well or well evaluated : ease of use – replacement of the battery, whereby it was observed that these individuals had considerable difficulty in performing this activity. It was also observed in some cases that the test persons were inclined to show appreciation for the rated products by arguing that they do so in order for the manufacturer to be more satisfied, or because they find themselves guilty of the result in performing a particular activity.

In verbal assessment, not confirmed by results of assessments, the least appreciated device was the one with LCD touch panel. Despite backlight, the lack of palpable keys was assessed by all respondents negatively. The ambiguity of buttons was also considered as something negative in most cases, which appeared in one of the remote controls as a result of the button marked with a 0/10. This button was confused with pressing 0 (zero) and hampered its search. The applied backlighting did not compensate for a small color contrast, particularly in the case of periodic operation of the backlight that was manually actuated. The application of NASA TLX tool allowed to state a greater implementation of the Temporal Demand and Frustration level, especially when performing maintenance activities - battery replacement and programming the device. Clearly, the tool showed a very large scale of differences between the noticeable components of the load among respondents. The problem among respondents when testing was a poor distinguishability of the analyzed components such as: Performance and Effort. It has been eventually decided that before continuing the use of this device for the evaluation of workload for the elderly it should be thoroughly verified in terms of applicability.

An important limitation during the process of studies was a number of compared devices - the tested subjects got quickly bored with repetitive tasks. Thus, in the future the usability of devices for the elderly need to also take into account this aspect. A general methodological note is that despite the lack of time constraints of tasks, the subjects felt intense stress and pressure caused by "The influence of the observer". They commented several times that the observation while performing tasks exerts a strong level of stress, which was also reflected in the results of the NASA TLX. The effectiveness of the work is dependent on many degradator (environmental hazards) of which stress plays a very significant role [2].

6 Conclusion

The conducted study had a pilot character and aimed to validate the research tools, hence the obtained results are only an estimate. Without a doubt, the identified criteria have important influence on shaping the ergonomic quality of control portable devices. The implementation of ethnographic design approach was very successful [3]. It revealed discrepancies between verbal assessment of the user and the real way of task implementation.

It should be noted that the devices that were specially adapted for the elderly did not fulfill part of its function – they were supplied with an unreadable and intricate manual, without drawings. The decrease in the number of function keys that was desired by older people in simple control tasks produced a significant impediment to nonstandard actions that needed to be performed using a combination of a few buttons. At the same time, it revealed the conflict between ergonomic quality of use, technical support, the programming and the exchange of power source.

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