Ergonomic Design of Computerized Devices for Elderly Persons - The Challenge of Matching Antagonistic Requirements

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Abstract. Aging implies a general decrease of physical and mental fitness, which, however, largely depends on training. Additionally, individual impairments occur more frequently with age. Three studies show that most elderly people struggle with the application of modern technologies, although physical communication is only slowed but not impaired and handling characteristics do not significantly differ from younger persons. Most usability problems originate from a lack of understanding the complex interaction of menu control. Former education and missing experience then tend to augment usability problems with time. Using the example of a mobile phone prototype it is shown that, despite the complex and inconsistent needs of elderly, the usability obstacles can be vanquished by considering the hierarchy of cause-effect relationships for design.

Keywords: Elderly persons, usability, input devices, menu control, product design.

1 Introduction

Improved working and living conditions enable a continuously increasing life expectance. In conjunction with low birth rates this leads to a demographic change with a significant increased percentage of elderly persons in many European and Asian countries. For example, in Europe actually more than 77 Mio. persons (equal to 20%) are older than 60 years, and this number is expected to double before 2030.

Manufacturers and service providers hence face a rapidly increasing percentage of elderly customers. To face the particular demands of this group, ergonomic aspects, particularly behavioral and cognitive ergonomic aspects have to be considered. The lacking empathic dimension for younger developers raise the question how to design products accommodating the (specific) demands of elderly persons.

In the following it is shown, that nor physical neither cognitive constraints have to be considered as major drawbacks for the usage to computerized devices by elderly persons, but individual reservations as a consequence of negative experience have to be overcome in order to provide elderly persons access and acceptance of modern technologies.

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2 The Process of Aging

Aging is mostly associated with a decrease in physical and mental fitness. Metabolic changes lead to a reduction of maximum forces and energetic performance beginning from the third decade of life. In a later phase information processing slows down and perceptual and mental performances decrease. Such changes affect all individuals, at varying ages and in varying levels of impairment. The characteristics of such biologically induced effects of aging are widely studied [e.g. 1-4] and build the basis for many ergonomics recommendations and checklists considering elderly persons.

A second type of age-induced variation of performance, which is also relevant for ergonomic design, occurs as a consequence of (mostly chronic) diseases, such as hypertension and rheumatoid arthritis. It is important to notice that the distribution among the population differs from the before-mentioned general gradients: only a part of the population is struck by such impairments, while other individuals are not affected.

A third factor of aging occurs as a consequence of resource utilization. This includes deterioration caused by chronic overload, but also the inverse effect - physical and mental degeneration as a consequence of passiveness. Such (in both directions negative) changes strongly depend on individual behavior, which is often consolidated by a lengthy positive feedback: A decreased performance provokes individuals to reduce or even to avoid corresponding activities, resulting in missing training and accelerated degeneration. This cumulative effect explains the increasing intra-individual variation of performance with age [5-7].

However, aging is not only associated with negative trends. Experience increases with age, affecting social behavior as well as strategic decisions [8]. This has important consequences also for technical products.

From a demographic perspective not only the percentage of elderly persons increases, but also age distribution changes, with important implications on ergonomics factors: improved working conditions and health care allow a life expectancy far above the retirement age. Most seniors are only marginally restricted by health impairments when retiring and during the first and often second decade thereafter. A new generation of "young seniors" with age related impairments but who are still active and demand for challenges (and have time and money) is developing.

Either way, it is desirable but not feasible to distinguish seniors as a special group of population. Aging is a continuos process, starting chronologically and physiologically with birth and ending with death. Thus, no strict classification for ergonomic design for elderly persons may be established.

3 The Impact of Modern Technology for Elderly Persons

Modern technology is not only a comfort feature, but fulfils more and more essential functions for life. Particularly for solitary and needy (elderly) persons communication and (health) supervision devices have a great impact on safety and independent lifestyle, which is identified as being the second most important factor for seniors after health [9].

Furthermore, modern technology becomes more and more an integral part of public organization, e.g. in form of ticket vending machines and mobile information services. This shifts the role of modern technologies from comfort and entertainment towards an element of infrastructure.

The subsequent dependency on modern technologies makes many seniors feel overloaded with daily activities. The assumption of congestion is based on the fast change of technology rather than on the function of technology. A particular problem is the lack of notice about changes and its access. Traditional infrastructure changes very slowly and changes are announced in public media. To keep up with technological change, on the other hand, users are required to update themselves regularly. Many seniors are not aware about this distinction and then react confused when confronted with new interaction requirements. So modern technology often causes uncertainty instead of providing safety and stability.

The role of ergonomics for elderly persons is thus much wider than only considering the pure human-machine interaction.

4 Study 1: Usability Problems of Elderly Persons

Modern devices are much easier to handle than ever. Small and lightweight devices require neither significant forces to be moved and activated nor particular motor skills for adjustment. Extensive functionality, options for individual settings and interactive control allow to adapt each device to very different user and usage requirements. State-of-the-art products are further rugged and almost safe in case of misuse. The decrease of physical, perceptual and mental performance with age thus does not affect usability of technical devices significantly anymore.

However, technical progress often provokes awkward changes for elderly users [10]. For example, the keypads of mobile devices contradict general ergonomic recommendations for keyboard size. They are usable if accepting lower speed and higher error rate. This is true also for elderly users, but more frustrating due to their motor and reaction impairment. Similarly, nearly all age-related deficits of perception, reaction and memorization will reduce performance but do not disable usability.

Considering the fact that any products should keep user requirements low in order to enable access to all levels of users, age-related physiological impairments explain only a minor part of user variance with all its disposition and training impacts. Thus, individual performance is rather a personal than an age-related attribute.

However, many seniors complain of significant problems when faced with modern products (Table 1). In a survey of 130 German seniors between 65 and 91 years more than 60% complained of problems when using technical devices. 30% have devices which they do not use any longer because of usability obstacles, and 40% had already refused to buy a device because it was expected to be to complicated to use. Although such a result is likely to vary between different countries, it draws a picture of significant usage problems for elderly persons.

For ergonomics design it thus raises the question, which factors provoke ergonomics problems and how to overcome such obstacles during product design.

Table 1. Consent rates surveying 130 German seniors (65 to 91 years old) for usability problems of technical devices (% of yes)

all (n=130)	females (n=71)	males (n=59)	<55 years (n=5)	55 to 64 years (n=50)	65 to 74 years (n=49)	75 to 79 years (n=10)	80 to 84 years (n=10)	> 84 years (n=6)
Do you frequently face problems when using technical devices?								
63%	67%	54%	80%	62%	61%	70%	60%	67%
Do you ask for an explanation before buying a new technical device?								
91%	91%	92%	100%	88%	92%	90%	100%	100%
Are you being instructed comprehensible when purchasing a technical device?								
41%	37%	50%	60%	35%	37%	60%	50%	67%
Do you use the manual when start operating a new technical device?								
97%	96%	100%	100%	98%	100%	80%	100%	83%
Does the manual helps you for problems operating a new device?								
60%	55%	72%	60%	68%	53%	70%	60%	33%
Do you have a possibility to receive help in case of trouble with technical devices?								
68%	68%	67%	60%	70%	69%	50%	50%	100%
Do you have devices which you do not use anymore because of usability problems?								
30%	33%	23%	60%	32%	29%	10%	40%	17%
Did you ever refused to buy a device because of its complicated usage?								
40%	41%	38%	80%	38%	37%	20%	60%	50%
Would you appreciate an individual instruction to get new devices operated?								
82%	84%	79%	100%	90%	80%	60%	80%	67%

5 Study 2: Usability of Input Devices

Operation of menu controlled devices becomes more and more common. The handling of such devices requires skilled motor control, with fast and precise movements and visual feedback. Such operations are expected to be more difficult for elderly persons in general, but with different characteristics depending on the type of movement required. This raises the question whether or not different types of input devices would be more suitable for elderly persons than for younger persons.

In a laboratory test the performance characteristics of six different types of input devices (see Table 2) were evaluated for younger and older users. The task consisted of a two-dimensional selection movement, which corresponds to many menu selection movements and puts similar requirements to the different input devices. In a 5x5 field matrix an indicated field had to be selected and then confirmed by pushing a button on the input device (see Fig. 1). Visual distance was 5m, the field size was each 3x2° with 0.5° spacing between the fields.

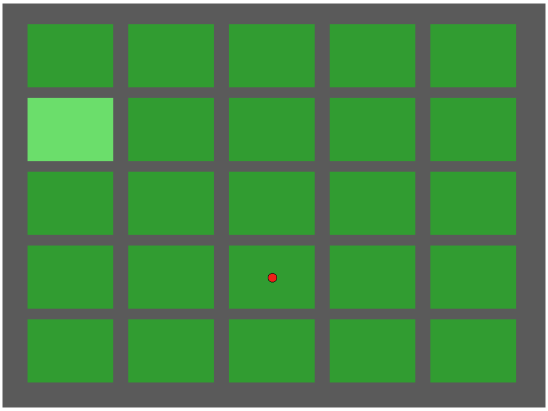
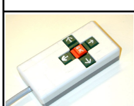


Fig. 1. Experimental task: The cursor (in form of a red dot) has to be moved to the highlighted field and then the mouse button has to be pressed

Each input device was tested for one minute repetitively (order of input devices permuted between subjects), and the whole set of 6x1 minutes was repeated 3 times (with a 15 min rest break in between) to check adaptation. The tests were performed with n=60 seniors (30 females and 30 males) with ages between 55 and 90 years and a control group of n=20 persons (10 males and 10 females) of 25 to 40 years.

Analysis was processed for execution speed, error rate, and learning function. Additionally a subjective preference was requested (detailed results in [11]).

Table 2. Rank order of handling attributes for different types of input devices evaluated for younger persons (25 to 40 years, n=20) and for elderly (55 to 90 years, n=60). Age groups and ranks are only separated for significant differences (p<.05).

Input device	Keypad	Trackball	Lightpointer	Drawing-table	Computer-mouse	Touchpad
						
Speed	4	4	1	1	1	4
Error rate	6 ≤ 40 yrs. / 3 ≥ 55 yrs.	1	3 ≤ 40 yrs. / 1 ≥ 55 yrs.	1 ≤ 40 yrs. / 3 ≥ 55 yrs.	3	5 ≤ 40 yrs. / 6 ≥ 55 yrs.
Subjective preference	3	5	1	3	1	5
Moved extremities	Finger		Wrist			Lower arm & fingers

The result showed a general decrease of speed and increase of error rate for seniors (average 1.5 s versus 2.3 s processing time and 2.0% versus 5.6% error rate). However, the ranking of the different input devices did not differ for speed and subjective preference between young persons and seniors (see Table 2). Error rate differed in detail between young and old, but general characteristics also corresponded for both age groups. Considering work experience with computers as a covariate showed that this factor is more effective than age for performance.

Input devices which are controlled by wrist movements (light-pen, computer mouse and drawing table) tend to provide the best overall performance.

Although keypads allow a discrete control and required less accurate movements its performances ranged below average.

6 Study 3: Usability Obstacles of Complex Electronic Devices

This study was intended to understand which problems occur and which strategies seniors apply to solve usage problems with complex electronic devices. It was expected to obtain a set of typically reported interaction problems of elderly persons (e.g. [12-13)

60 seniors (55 to 91 years old, each n=20 in the age groups 55 to 64, 65 to 74 and more than 74 years; complemented by a control group of n=20 aged 25 to 40 years) were asked to adjust the ring volume of a mobile phone. Three different types of common mobile phones were used (Nokia 3310, Motorola Timeport L7089, and Mars Trium), and subjects were not instructed for any specific usage in order to discover their exploration strategies. Interaction was stored on video tape and subjects were retrospectively asked to explain their behavior.

As a general result, button control and visual perception caused problems for 19% and 25% of all seniors. The 25% visual perception problems in this case were mostly associated with difficulties to recognize symbols and abbreviations, only few problems (4%) were caused by optical obstacles (seniors used reading glasses if convenient). The 19% button control problems occurred due to difficulties to identify buttons and selective activation without pressing a second one; some few problems were caused by insufficient feedback. However 84% of seniors faced problems with the logic of interaction (menu control), 70% got stuck without finding a way back (almost equally assigned to each of the three mobile phones).

A first conclusion could be drawn in a way that a major problem has to be seen in the complexity or inconsistency of the menu logic. A detailed study, initiated by a randomly observed incidence, showed that this interpretation would be mostly wrong: during one test, an senior held the mobile phone in a way that he covered a central part of the display with his thumb. Under normal circumstances menu control would be disabled due to the missing visual control. However this person continued typing to fulfil the task (adjusting the ring volume). When he was subsequently asked if he would not feel restricted, he reacted visibly confused by the question and denied.

Checking the background of his reaction it turned out, that he did not expect displayed information for menu control, but only tried to figure out a successful sequence of keystrokes to adjust the ring volume by chance. A retrospective inquiry of all seniors showed that almost all persons struggling with menu control (66% of total) did not use display information for navigation, but only sought for a suitable key sequence. They expected young persons to memorize the appropriate key sequences and themselves being too old to keep this information stored. Observing other persons using their mobile phones they just realized how fast they pushed the button, but the visual control use of the display was not observable. Many of the seniors wrote down important commands for the use of their TV-sets by noting the sequence of buttons to be pressed.

Thus, a more general problem of menu control has to be seen in the interactive character of activating functions by selecting from the options on the display than in the consistency of the logic itself. In fact, neither memorization capabilities nor intelligence have ever been limiting factors to access menu controlled devices (except considering extremely bad designs).

Persons who are aware how menu navigation works in principle mostly figure out an individual set-up and cannot imagine other persons not knowing the interactive character of this type of interaction. This might be the major reason why developers (and in this case even ergonomics researchers) do not expect this case being relevant (but in this study was for more than 60% of the senior users).

7 Discussion and Interpretation of Studies

The three studies mentioned before show that the interaction with modern technical devices is somewhat slower, less comfortable and sometimes require additional aids for elderly persons (e.g. lenses), but there is no objective barrier for use. However, many seniors complain extensive problems when trying to use modern technology (see Table 1).

The barriers to use modern technologies are obviously not caused by decrease of perceptual, motor or cognitive performance. Experience of modern technology rather seems to be a key factor. Experience again largely depends on individual attitude to modern technologies.

There is no reason to seek the difference in open-mindedness to new technologies between young and old persons in constitutional factors. Hence, cultural environment and educational factors should cause such effects. Elderly persons formerly experienced a different type of technology and means of accessing it. Some decades ago modern technology was associated with extensive power (e.g. motor vehicles) and/or it was mechanically sensitive. Either way, technology was expensive and sensible to damage. Already now seniors report fear of damaging technical products in case of misuse - however the usage of today's products is mostly explored by trial.

With time, demureness and trepidation are recursively boosted: careful and distant behavior to modern technology isolates from new developments in a way that users avoid to get in touch with it. When using modern technologies the likelihood of usage failure is quite high because of the missing experience. The resulting frustration provokes an even more distant behavior to modern technologies. This is particularly apparent after retiring from work life, suspending the necessity to cope with new developments.

Experiencing a reduction in performance with age decreases self-assuredness and confidence of control, e.g. for physical stability and mental reliability. This experience additionally amplifies the feeling of uncertainty to use modern devices.

The increasing sanity is recognized as a positive attribute of aging [8]. However, being more rational may result in a more conservative behavior which again constrains openness to explore new technologies.

Thus, the formation of technical skills depends much more on experience with new technologies than on age. It seems to exist one offensive group of seniors which almost does not face any usability problems at all, and another defensive group of seniors who have shaped a more negative attitude to modern technologies.

8 Conclusions for Ergonomic Product Design

The physical, perceptual and mental restrictions of aging touch elementary ergonomics requirements and are still important to consider. However, any particularly visible emphasis of ergonomics attributes (e.g. large buttons, striking colors) provokes to stigmatize the user of such a product as an impaired person needing particular equipment (examples in Fig. 2). In this respect ergonomics requirements and social categorization need to be subtly balanced.

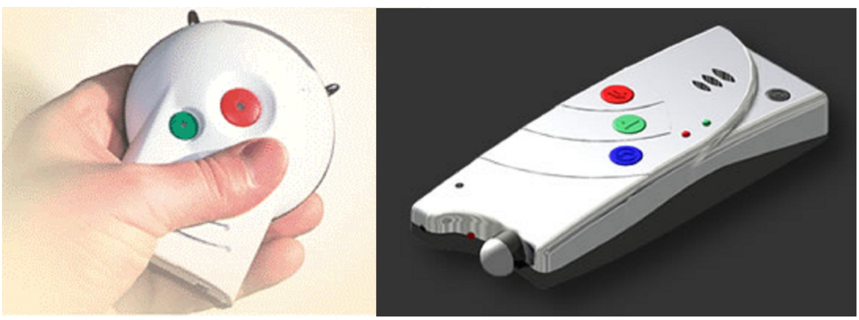


Fig. 2. Commercial communication products designed for elderly users lack acceptance because they often provoke a stigmatization

In order to overcome a lack of user experience it is not sufficient to provide a product design which is only easy to use. Additionally such a product shall help to overcome fears and reservation in order to explore and experience new technology.

Thus products for elderly persons must not address interaction performance deficits in a way they become visible (although this might imply some performance deficits, but not disable usage). Rather they must support older users to explore new options and functions by shunning fears of inexperience and incompetence.

This is a particular challenge for the design process, as most developers may not have an emphatic insight to this problem and those effects may not be illustrated by functions or characteristics. A suitable form of participation is thus a key for product development, particularly during the conceptual phase. But users again may not easily express their demands at this stage, but focus mostly on device requirements. During the studies performed by the author, user representatives only concentrated on interaction deficits which turned out not to be the key ergonomic deficits. Introduced forms of participation in product development (e.g. [12]) thus provide only limited access or require extensive prototype building and re-engineering. Advanced forms of user participation for this issue still have to be developed [14].

An application example, a mobile phone prototype, shall show how to meet the (partially inconsistent) design requirements for a final product (Fig. 3, [15]).

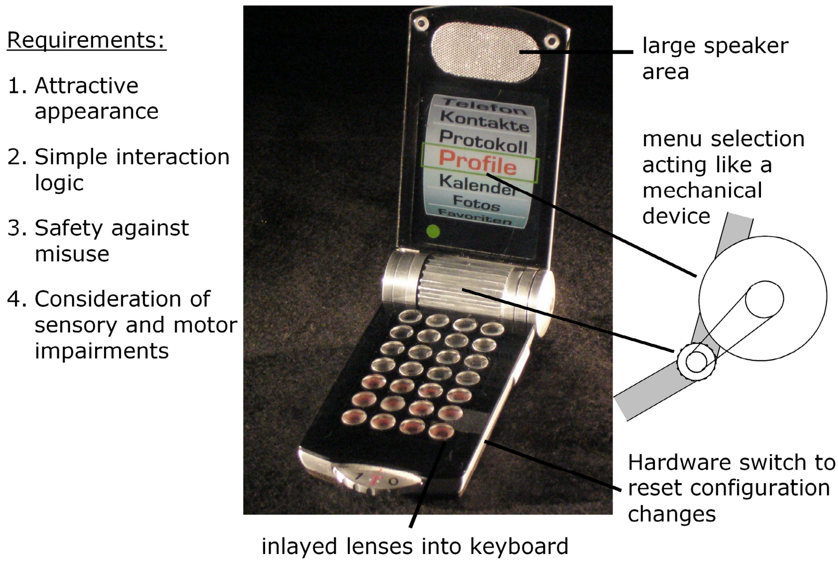


Fig. 3. Requirements and prototype of a mobile phone addressing the needs of elderly persons

Product aesthetics is the first and often singular attribute enabling to attract a potential user's interest, because a product receives no further attention if this is not achieved. It is thus essential to be attractive in the users perception (which are mostly sportive attributes even for seniors) and must not risk to stigmatize the user. For the mobile phone it was aimed to create a shape which is conform to the aesthetic demands of seniors and is equally assumed to be attractive for their children and grandchildren.

A product then has to convince potential users for its safety against misuse. In the mobile phone example a simple hardware switch was added to reset any changes in configuration to a previously defined state. A selectable time range for undoing changes (e.g. to come back to the configuration used the day before) may be applied as an extension.

The proposed mobile phone uses a mechanical correspondence to access its functionality by menu control: A rotary cylinder moves a correspondent virtual cylinder on the display in a way as they would be coupled mechanically. Selection is then performed by pressing on the rotary cylinder. In order to avoid overload when not being already familiar with all functions, options for a stepwise reduction of functionality (starting with a simple number selection and connect/disconnect function) are provided. The physiological particularities of seniors are further addressed, e.g. by inlayed lenses into the keyboard. So button description can be read without using lenses. However, the size and the appearance of the phone does not differ significantly from common mobile phones.

This example shows that the consideration of the hierarchical cause-effect structure of physical and psychical aging may help to design products being usable and attractive for elderly as well as younger persons.

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