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Aging and ergonomics:
The challenges of individual differences and environmental change

James L. Fozard
Jan A.M. Graafmans
Jan Rietsema
Herman Bouma and
Ad van Berlo

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AGING AND ERGONOMICS: THE CHALLENGES OF INDIVIDUAL DIFFERENCES AND ENVIRONMENTAL CHANGE*

James L. Fozard, Jan A.M. Graafmans, Jan Rietsema, H. Bouma, and A. van Berlo
Center for Biomedical and Health Care Technology
Eindhoven University of Technology

ABSTRACT

Aging is universal but not uniform. Genetic differences combine with unique life experiences resulting in differential exposures to disease, environmental trauma, and variations in the built environment. Heterogeneity, not homogeneity characterizes the process of aging as well as its results, as observed in persons or groups defined by the calendar as old or elderly. Heterogeneity means that specific applications of ergonomics for the elderly will require full application of the dynamic systems concept of human factors theory, i.e., task modification or the selection, training, or adaptation of the person or some combination of both to achieve a desired systems outcome. Moreover, because aging itself means change, the design of environments and equipment used over the lifespan should include the potential for changing requirements associated with aging. Designs based on developmental principles — e.g., systems that have the potential for stimulation and challenge as well as accommodation to human capabilities — have the potential for changing conventional concepts of human aging. Finally, secular changes in the complexity of the built and technical environment requires that system design helps prepare users for further changes, not simply for adaptation to the current system. These ideas are discussed in relation to criteria for human factors research on aging, manpower development and pragmatics of design.


INTRODUCTION

Mr. Chairman, ladies and gentlemen. I want to thank Professor Jan Moraal and the members of the program committee for inviting me to participate in this 10th anniversary meeting of the European Chapter of the Human Factors and Ergonomics Society. I am especially pleased that the theme of the meeting is human factors and aging. I realize that aging is not a popular topic among most ergonomists nor laymen, but it is of relevance to all of us. I am convinced that there is not a parent in this room who would want his or her teenage daughter go on a date with a boy who had a reputation as bad as aging or old age. One reason for aging's bad reputation is the common association between disease and disability and old age—like the gentleman in
the cartoon who says "If I knew I would live this long, I would have taken better care of myself." In fact, the bad reputation of aging has its beginnings in early development and poor parental training is largely at fault. One sees this reflected in two children's cartoons about aging. In one, Dennis the Menace asks his father's friend, "...and what age are you in the middle of?" In a second, the little boy asks his grandmother, "...if I'm only young once, then how many chances do I have to be old?" These ingenuous remarks suggest that we parents are not doing such a good job educating our young about aging. In an ideal world we would pass through our lives being as smart and wise as the old man who in response to the question, "How old are you?" said: "What age do you mean, my anatomic, physiologic, psychologic, moral,....or chronologic?" The old man is smart because he can make all those distinctions; he is wise because he put chronologic age at the end of his "list" of ages. The remark of the old man highlights a major theme in this talk--namely that there is no single identifiable group, "the elderly." The cumulative effects of individual differences in genetic makeup combined with a lifetime of unique experiences combined with various exposures to illness and environmental stressors mean that coevals by the calendar will be, most likely, less alike one another in old age than earlier in life.

HUMAN FACTORS AND AGING OVER THE PAST DECADE

The tenth anniversary of the European Chapter of the Human Factors and Ergonomics Society roughly corresponds to some significant advances in the specialty area of human factors and aging. For starters, consider the Human Factors and Ergonomics Society itself. In February, 1981, the first special edition of Human Factors was published with seven articles. Almost all of them were theoretical essays or literature reviews. I was the editor of that special issue which I dedicated to the memory of a great pioneer in ergonomics and in human factors and aging, Dr. Ross McFarland. Fifty years ago, McFarland published the "Older worker in Industry." Almost all of the articles in that special issue were solicited by McFarland or myself.

In October, 1990, the second special issue of Human Factors was published under the editorship of Dr. Sara Czaja. The advances in human factors and aging over the decade were everywhere evident—enough papers that a sister journal, the International Journal of Industrial Ergonomics was persuaded to take the overflow. In contrast to the first special issue, there were several empirical papers in the special issue and its overflow, including a report by Clark, Czaja and Weber (1990) of the advances in the task analyses of everyday activities, such as bathing, meal preparation, shopping etc. The overview article by Smith (1990) was able to report and comment on a much more dense and active decade than was possible by Fozard (1981) in the first special issue. In addition to the special issue, an overview of the potential uses of research and practice in human factors and ergonomics for an aging population was published in the Society's Technical Bulletin by Fozard and Fisk (1988).

Another important development in the Society was the steady growth of the Technical Group on Aging, founded in the late 1970s through the efforts of Arnold M. Small. Dr. Small served as the first chairman of the group, edited the Newsletter and recruited members almost single-handedly for a period of years. The second chair was Dr.
James Baker, followed by myself for a period of four years. During my tenure as chair of the group, Drs Small and David Smith, and a few others did a lot of missionary work. By the time I served my last year as chair, the Technical Group had a good enough infrastructure that there are now annual elections of officers, a very lively newsletter and vigorous planning for the annual scientific program. As in the case of the second special issue of Human Factors, the annual programs have included progressively more empirical papers from a variety of sources. Members of the Technical Group on Aging are organizing a session on aging for the International Ergonomics Association to be held in Canada in 1994.

In the United States another significant milestone was the 1990 publication of the National Research Council report "Human Factors Research Needs for an Aging Population" edited by Sara Czaja. The National Academy of Science Committee on Human Factors identified a panel that represented members of the Human Factors and Ergonomics Society as well as experts from other disciplines. That document, along with the 1985 Congressional Office of Technology Report on Technology and Aging did much to alert government and other groups interested in aging to the possibilities of using human factors knowledge and skills to promote and maintain the independence of older persons.

David Smith (1990) identified several other significant events, including the convening of the conference on the older driver sponsored jointly by the Department of Transportation and The National Institute on Aging. One outcome of the conference was the publication of another special issue of Human Factors on that topic. He cited the publication of the first chapter on human factors and aging by Charness and Bosman (1990) in the third edition of the Handbook of the Psychology of Aging.

A major problem in developing the research side of human factors and aging is support for research projects--particularly in a field where the predominant support has been from the military and defense communities. The decision of the National Institute on Aging to begin supporting human factors research and the assigning of staff to carry it forward was an important development. Although the budget available for the research is very small by Department of Defense Standards, and there is considerable difficulty in getting the peer-review machinery in place at the National Institutes of Health, there has already been a substantial number of projects initiated with this support. When Chapanis (1974) argued that human factors specialists needed to diversify their interests into nonmilitary problems such as those associated with aging, he was truly in advance of his time. Almost twenty years later in 1993, the need is obvious and current.

In Europe there has also been a substantial increase in interest in human factors research and practice towards the elderly. For example, design activities have been strong in Britain, Sweden, and research on aging and work has been strong in Finland and the Netherlands. One of the most important recent activities in the Netherlands has been the development of "Gerontechnology." The conference and publication of the book on the topic sponsored by the Eindhoven University of Technology has been a major stimulus for interest in the use of technology by and for the elderly (Bouma and Graafmans, 1992) Gerontechnology and human factors as applied to aging overlap
in many ways but there are also important differences. They both use the lifespan developmental view mentioned above as a theoretical framework and they both are concerned with age changes in the interactions of people and equipment and products. Gerontechnology differs from human factors inasmuch as it does not include changing person/environment interactions by training, counseling or selection of people, except for the technology that might be involved in such efforts. Also gerontechnology is directly concerned with the impact that secular changes in technology have on the adaptation of older persons to those changes.

I would like to spend the remaining time discussing the future directions of human factors and ergonomics as they apply to aging and the aged. There are four areas of concern: the conceptual basis for future work, the research and knowledge base, the development of manpower, and the pragmatics of design and evaluation.

CONCEPTUAL BASIS FOR FUTURE WORK

Smith (1990) identified two broad models that have guided human factors and ergonomics thinking with respect to aging. The first, articulated by Faletti (1984) and Lawton and Nahemow (1973) focusses on physical and psychological decline with aging; the decline is seen as a person-environment problem. The role of human factors is to improve the match between human capabilities and demands of the environments--to optimize the fit between the human operator and the equipment or environment in which the person functions. Task analyses such as those initiated by Faletti (1984) and further developed by Czaja and her colleagues (Clark, Czaja and Weber, 1990). As human capabilities with respect to sensory, cognitive and mobility functions decline, tasks and environments of the person are adjusted to enable the person to continue functioning.

The second, articulated by Fozard and Popkin (1978) and Fozard (1981) emphasizes the developmental aspects of aging. Smith (1990) summarized their main ideas: "...the ideal approach to design for the elderly would (a) accommodate aspects of constancy and growth as well as decline; (b) be sensitive to social and psychological needs as well as performance needs; (c) because both people and environments change, acknowledge the temporary nature of generalizations about aging." (p.511) Training, needs assessments and counseling are additional useful methods of study and intervention to task the task analytic approach used by Faletti.

Both of these views share the central philosophy of human factors--a systems approach toward aging. The philosophy is well articulated by L.E. Morehouse(1958): "The ultimate aim of each human factors effort is toward the optimal utilization of human and machine capabilities to achieve the highest degree of effectiveness of the total system." With respect to research on human factors and aging, Robin Barr (unpublished) put it well: "The promise of human factors research ...is contained in the control over performance that can be achieved by altering the dynamic of the operator-task environment." The implication of this philosophy for human factors practice as well as research and aging is that aging itself cannot be defined independently of the environment--age grading of human abilities and functioning only has meaning in reference to environmental challenges and supports. It is largely for this reason that the NRC
A report on Human Factors for an Aging Population (1990) identified as the highest research priority the need for "good distributional data on tasks, problems and abilities and to perform detailed task analysis where the benefit is likely to be the greatest..." (p.66).

The relationship between the developmental view of human factors and aging and the systems approach is illustrated in the next three slides.

At any point in time the interaction between a person and her or his environment may be characterized by the two dimensional figure familiar to human factors experts. Starting on the center left and going up, information is received from the environment-perception. Events within the person results in actions which may adjust or modify controls of the technical operating system which may be a vehicle, a device at work, or a housing system.

In the next slide, the center box spanning the interface line in this version of the stan-
Standard systems diagram is particularly important because it identifies the environmental considerations—both internal and external—that must be taken into account in human factors applications involving age differences among persons. Age associated differences in sensitivity to the visual, acoustic and thermal environment as well as individual differences in strength, cognitive abilities, etc., are the main things that determine whether it is necessary to age-adjust the relationship between the human and technical operating system. Whether the contrast characteristics of a visual display for a particular application is optimal for both a young and old adult may depend on differences in sensitivity to ambient light conditions and many other conditions. Most human factors research related to aging deals with these problems.

The developmental view of human factors also adds a dynamic aspect to the systems concept as indicated by Smith (1990). This is illustrated in the next slide by the time dimension or "time track" along the bottom of the diagram.

The "0" denotes the present, "-" the past and "+" the future. Because both technology and the environment change over time at the same time a person is aging, personal aging and the time period during which a person ages are interdependent. Technology introduced at the present time (0 on the time axis) may affect how young and old persons adapt to it (- to 0 on the time axis) and it may alter the course of aging itself (0 to + on the time axis).

Perhaps the most interesting implication of the developmental view of human factors is that ergonomic interventions should emphasize adaptability of architecture and products as a design principle. In housing for example, the interface between equipment and appliances and their user may change over time even though the function of the equipment/appliance does not. Over time the requirements for space utilization may also change either because of age changes in the needs of the occupants or because of the desire to accommodate to newly introduced technology or products. The adaptability principle is now reflected in changes in form, e.g., movable interior walls.

The developmental view of human factors and aging outlined above suggest five ways in which human factors and ergonomics can address aging. These are illustrated on the next 5 slides.
At the center of the diagram is "prevention." Many "problems" of old age are modifiable through long-range, nonmedical interventions involving nutrition, physical activity, exposure to chronically dangerous environmental conditions such as auditory noise, changes in lifestyle regarding alcohol and tobacco consumption, etc. How can human factors address prevention? Using physical activity as an example, technology for monitoring ambulatory levels of activity in everyday situations, and the design of exercise and recreational equipment that is fun to use, i.e., has a high positive motivational quality, and the design of ambulatory monitoring or warning equipment for improper posture for specific tasks such as lifting and general posture to prevent or slow the development of kyphosis. Recently Pendergast and colleagues (1993) proposed age associated criteria for several aspects of aerobic and strength abilities for adequate functioning in old age. Using as a reference the level of a 20 year old, they recommend as a minimum level: 10% of aerobic capacity; 40% of peak anaerobic metabolic power and sustained anaerobic effort; 40% for ability to sustain a muscular contraction and 40% for ability to generate a maximal force. These represent the first scientifically based effort I know of to establish minimal goals for lifetime fitness and provide a basis for devising fitness programs.

Another example comes from the study of age changes in hearing thresholds. The next slide shows ten year changes in hearing thresholds for very carefully screened men and women ranging in age from the 20s to the 80s at time of first testing. The slide shows that average change in hearing level per year for frequencies ranging from 250-8000 hz. The dramatic difference between men and women is tentatively attributed to differences in chronic exposure to environmental noise. Any person in a group who had any evidence of noise induced hearing loss based on audiogram evidence using Kryter’s (1974) criteria was eliminated from the analysis. Comparison of the men who had evidence of noise induced hearing loss with those whose data are shown in the slide, indicated that in addition to higher initial thresholds, the rate of hearing loss associated with aging was relatively greater. The use of technology to monitor levels of noise in ordinary settings and to help reduce exposure to noise over the lifespan could reduce the prevalence of impaired hearing in old age.
At the top right of the diagram is "compensation". The vast bulk of existing human factors efforts in aging focuses on this issue. Examples include improved lighting for various visual tasks, mobility aids, devices to improve ability to carry out ADLs, etc. In the case of lighting, a unique demonstration project in the Netherlands includes the assessments of home lighting as part of the evaluation of the clients, most of whom are elderly, and the visual aids prescribed for them. (Neve, Jorritsma and Kinds, 1993). Because lighting requirements are relatively task specific and there are such substantial individual differences in the visual abilities of older persons, I have recommended the increased use of flexible lighting systems in both work and home visual environments (Fozard and Popkin, 1978; Fozard, 1981). This recommendation has not been evaluated. The primacy of design of fixed lighting devices, e.g., floor, lamps, wall lamps and ceiling light systems is obvious to any visitor to a lighting shop, although recent developments of small intense light sources such as halogen lamps has been accompanied by more flexible lighting appliances.

Improved lighting of stairs, particularly in the home would also benefit the elderly inasmuch as most falls by them on stairs occur on the initial step of the flight of stairs, the step for which visual guidance is most important (Fozard, 1990). A simple design possibility would be to have a pressure activated switch on the floor near the top of the flight of stairs turn on a light that would illuminate the stairs for a short period of time while the person is traversing the steps. Lighting and step width and width are probably not the same for ascending and descending stairs.

At the top left of the diagram is "enhancement". Aging brings with it challenges, which are addressed be compensation and prevention as described above. It also
brings opportunities in the form of time for new social interactions and activities, time for new learning and leisure activities—self fulfillment. There has been virtually no attention paid to this aspect of aging by human factors and ergonomics. The exception is the design of adaptable housing to suit the differing needs of people during the life cycle of the family. The potential uses of technology for enhancement of activities is particularly intriguing.

What are some ways in which human factors and ergonomics can contribute to enhancement? One potential area is in user-friendly technology in communication to facilitate remote contacts with family and friends, to make new contacts and to participate in educational activities remotely. Another area is in the development of user-friendly computer systems for games, artistic and creative activities and learning through multimedia technology. The experiences as well as ages of potential users of technology vary with respect to the timing of introduction of technology and the user-friendliness of ergonomic design must include features that interest and motivate older as well as younger adults.

Toward the bottom of the diagram is "aid to caregivers". Ergonomic analyses and design of devices to lift and transfer people who cannot move themselves and devices that assist caregivers in providing assistive and medical care are included in this category. One of the most significant recent developments in home based medical care is the widespread use of complicated medical equipment by family and other nonprofessional caregivers, e.g., respirators, intravenous injection devices, monitoring equipment, etc. As many of you know the Human Factors Society is involved in the preparation of human factors guidelines for such equipment by the American Institute for Medical Instrumentation. Many of the developments designed to help individuals remember medication regimens currently undergoing ergonomic analyses as described in last month's Human Factors and Ergonomics Society Convention would be of equal use to caregivers.
enhancement

compensation

prevention

aid to caregivers

improve research on aging

On the very bottom of the diagram is "improve research on aging". As in the case of "aid to caregivers" the contribution of human factors to aging and the aged is indirect. It is a truism that technology is revolutionizing the scientific study of physiology, psychology and biology, and this is equally true for observational and interventive studies of aging. The impact is enormous both on data currently collected and in the reanalysis of archival information. An example of the former in the National Institute on Aging's Baltimore Longitudinal Study of Aging is the study of differences in the dynamics of the strength training in young and old persons. An example of the latter was the use of electronic scanning devices that allowed twenty-eight years of historical data on pulmonary function to be digitalized and analyzed according to the same criteria for research quality pulmonary function data.

RESEARCH AND KNOWLEDGE BASE FOR HUMAN FACTORS AND AGING

I would now like to discuss the research and knowledge base for human factors and ergonomics in relation to aging. As you are aware there is wide variation of opinion about the value of existing research for human factors and ergonomics applications. One of the founders of the field, Alphonse Chapanis has been one of the strongest critics. Yet, in the field of human factors and aging, one of the most influential publications is the National Research Council report entitled "Human Factors Research Needs for an Aging Population". Research that describes how old people spend their time heads the list of priorities for action according to that distinguished group. What should the future development of research be that meets the criticisms of Chapanis and promotes the scientifically based information the experts in our field need?

One possibility is to repeat the major human factors research studies adding age as a variable. The obvious difficulties with this approach include deciding on what the major studies are, and assuring that the data obtained are relevant to the needs of ergonomics practitioners. Another approach advocated in the report "Human Factors Research Needs for an Aging Population" is to do task analyses on the major classes of activities engaged in by the elderly and to recommend general design recommendations based on identified human limitations in strength, flexibility, mobility etc.
The task analysis approach is good because it identifies environmental demands in tasks which can be remedied by task redesign. Additionally the redesign will facilitate performance by persons of all ages. The tedious and time consuming process of task analysis and the specificity of the results to particular activities discourage the widespread application of the method.

A third approach to the choice of research which encompasses the two just mentioned is based on a combination of the developmental approach to human factors and ergonomics activities and the criteria for "optimal performance engineering" proposed by Donald L. Fisher (1993). The centerpiece of both ideas is that the ideal human factors research activities and the reporting of research results would be in terms of performance of an "optimal system." This 'back to basics' concept is at the core of human factors theory as defined by Morehouse in 1958. In it, the mix of human and machine functions that yields optimal system performance is identified in such a way that rules are generated which predict how assignments of function to man and machine should change as system requirements change or in the case of aging what combination of mechanical and human components, if any, will yield equivalent system performance given a nonremedial age related change in the capacity of the human.

In my review of the human factors and ergonomics field in 1981 (Fozard, 1981) I proposed that wherever appropriate, human factors research utilize adaptive experimental approaches. The reason for that recommendation was to focus the research on the output of the man-machine system rather than the interaction between age and task difficulty. The literature available at the time was based on analysis of variance type research designs that almost invariably showed an interaction between task difficulty and age. The limitation of the literature was that the range of task difficulty represented in the study was unclear and the age range was inadequately sampled. The advantage of the adaptative experiment was that it would relate the variables studied directly to performance. For example, in a paced inspection task in which one was trying to identify the best combination of frequency and rate of presentation of target and distractor stimuli, one would first specify the desired system outcome, e.g., 80% correct identifications of the target with an acceptably low level of false positives, one would vary the rate and frequency of target presentation to identify the values of those parameters that yield the desired level of performance for persons who differ in age, sex, or some other characteristic.

Fisher's (1993) criteria for the best human factors research is based on optimal performance engineering. Fisher (1993) states that human factors design evolves through three stages--good, better, best. A good design may be the best, but because it is not arrived at without documentation or active consideration of other competing approaches, the best that can be said of it is that it is good. Better design is achieved when several solutions are proposed and evaluated in a way that incorporates proper controls. The best design is achieved when there is a theoretical basis for generating a large number of potential alternatives, and a basis for selecting and testing the most promising ones. The result is an optimal solution as defined by Morehouse (1958). Fisher then goes on to classify dozens of examples of research according to three categories of studies--empirical, theoretical and analytical. In each case he tried to
show how the study examined approached the ideal of the optimal performance engineering. Accordingly, the idea that ties the examples of all three classes of research together—empirical, theoretical and analytical—is that they approach the ideal of optimal performance engineering. Fisher provides an informal definition of optimal performance engineering "...a study can qualify as an instance of optimal performance engineering only if behavior is predicted or observed over the entire range of at least one design or environmental dimension." (p. 131) He then goes on to provide rules which govern what he calls the optimization process. He concludes with a spirited defense of the applicability and usability of human factors research if the research meets or approaches the criterion of optimal performance engineering. Because Fisher's criteria for quality research is solidly based on a systems approach, it seems to me to represent a good starting point for deciding the best strategies to use in generating research on human factors and aging. The task analysis approach of Faletti (1984) elaborated by Czaja and colleagues would qualify as approaching Fisher's criteria because it covers a wide range of situations. The adaptation of Pitt's Law on the basis of age and sex proposed by Brogmus and colleagues (1989) is another. If suitably extended to include other variations, the work on age differences in sensitivity to stimulus response compatibility could be another.

DEVELOPMENT OF MANPOWER

Who will and who should carry the torch for human factors and aging? The academic base for training scientists and practitioners in human factors and aging is very, very small. In the United States as in Europe, the traditional university base for training people in human factors is in departments of psychology or industrial engineering, and to a lesser extent, schools of architecture and design. In the United States, university programs that have promoted this area include, the Georgia Institute of Technology (Prof. Dan Fisk), the University of Southern California (Professors Smith, Small, Boyd), the University of Buffalo/University of Miami (Prof. Sara Czaja) Many other universities have graduated students with advanced degrees based on research related to human factors and aging including the University of Kansas, University of Dayton, University of South Dakota, University of Georgia and Virginia Polytechnic University. The development of research support mechanisms, largely through the NIA will increase the potential for training of graduate students in human factors and aging, a process that has already begun.

In the Netherlands, an ambitious and systematic effort to develop a University-wide educational and research program in gerontechnology has been started at the Eindhoven University of Technology. This includes the funding of doctoral level research projects. It is broader in scope than any others that I know of. You will hear more about this program in the presentation by Mr Graafmans.

For the foreseeable future the development of academic specialization in human factors and aging will have to proceed without a clear concept of the employment opportunities for the students who are being trained. This is also true for persons trained in schools of design and architecture. In a very important sense, the university is the best place for the development of human factors and aging, because it can respond to the demographic changes in the age distribution of the population at the same time
respond to the changing needs for human factors training of young engineers and scientists. In contrast, industry has too short a time perspective at least for the present. Government agencies, being politically driven, also have a short term planning horizon even though such agencies may create the demand for human factors solutions for "problems of the elderly."

PRAGMATICS OF DESIGN AND EVALUATION

Just as aging and old age are not popular, neither is the idea of human factors for the elderly and the aging. A frequent observation by designers and marketers for products for the "mature market" is that a potential customer says--I don't need it because I'm sick and I'm not old. Conventional wisdom suggests that design should focus on needs that may or may not be age related as should marketing of products and technologically based services.

One of the serious problems in developing human factors research in aging is the lack of input on the perceived needs of older persons and the use of them in evaluating products and services. The idea of a "mature consumers union" has been suggested by many persons. The difficulty with such a scheme is that products endorsed by such a group would suffer from association with the bad reputation of aging. Nevertheless the requirement for product evaluation with respect to ergonomics remains a major need for people of all ages. The special issue of Applied Ergonomics in the summer of 1993 provides many examples of the successful use of elderly persons in product evaluation in Sweden and the United Kingdom. I believe that the major ergonomic adjustments of products required for optimal use by the elderly will also benefit the younger adult so that product evaluation can be carried out in such a way that does not stigmatize the product.

CONCLUSIONS

Thank you for the opportunities to reflect on the current and future status of human factors and ergonomics as it applies to aging. In this presentation I reviewed the progress in this field over the ten years that the European chapter has been in existence. I recommended the continued use of the developmental or lifespan view of ergonomics as a basis for organizing efforts in this field. I suggested that we use Fisher's criteria for quality research as a basis for carrying out research on human factors and aging. I argued that universities should take the major risks inherent in developing manpower for efforts in human factors and aging. Finally, I recommended the use of the elderly in carrying out ergonomics evaluation of products.
REFERENCES


