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Human Variability and Ergonomic Design

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Introduction

In an anthropological perspective the analysis of interaction processes between people and technologies in different life and work activities needs to consider all the social, cultural and physical aspects that denote categories of persons or well defined human groups. Such aspects can be declined through a series of characters presenting a large variability, that has to be considered in designing and testing any system conceived to satisfy the largest number of people. In most ergonomic design applications involving the interaction with tools, instruments and systems, well defined information about the population of users is required. Differences in body shape, size and physical capacities are the most obvious manifestations of human variability (Herron, 2006; Meunier *et al.*, 2009), but there are several other differences relevant for ergonomic design. The prescription of the 28th article of Italian legislative decree 81/2008 clearly refers to this concept, as it demands to examine all workers safety and health risks and also those related to gender differences, age and provenance from other countries. However, such decree, that states the need to apply the ergonomic principles, concerns only the workplaces and therefore tends to protect just the working-age population.

The variability of subjects at the age extremes

The ergonomic design involves all the interactions of people with the built environment and should consider all the possible users categories, as well of special demographic groups, as children and elderly, that show a huge variability related to growth and aging processes. Subjects at the age extremes can be the users of many systems. They show an high variability related to both growth and aging processes and present peculiar requirements, sometimes not adequately studied, compared to working-age population, although there is a growing attention to this problem. For instance, in ISO Standard 20282 (2006), that provides requirements and recommendations for the design of easy-to-operate everyday products and defines a testing method to measure their usability, it is argued that age has deep effects both on physical and psychological user characteristics and, consequently, it is necessary to consider also children and elderly requirements.

Subjects growth in the age of development is a complex phenomenon that involves morphological, functional and psychological modifications that lead the individual to the adult's structure and characteristics. Due to the huge inter-individual variability in the growth extent and times, even the population of children and adolescents of a single class age shows a remarkable variability.

The aging process involves the individuals in different ways, as proved by the different life expectancy of various social and professional categories; moreover, in the same individual that process changes from organ to organ and from a time interval o another. Consequently persons grow old through different modalities, at different speed and different ages and the elderly population turn out to be particularly heterogeneous. It is essential to care about these aspects not only in the design of products and services meeting the needs of the elderly, but also in defining the occupational policies of aged workers. Generally it could be difficult to estimate if some workers will be able to obtain certain performances, as the specificity of the physical and psycho-social work environment can further affect the variability of elderly workers'performances and abilities (Fubini, 2010). As pointed out by Contini (2003), they should be able to work fewer hours and with less stressful and exhausting tasks, requiring more experience and good sense than physical resistance. Therefore they should be able to choose more flexible working arrangements to be able to continue to work according to their functional capabilities.

The ageing workforce is one among the top 10 emerging psychosocial risks revealed by a group of experts'of the European Agency for Safety and Health in Europe (EWCS 2007). They emphasized the fact that ageing workers are more vulnerable to poor working conditions than young workers. Additionally, the failure in providing ageing workers with lifelong learning opportunities increased the mental and emotional demands upon them, which may affect their health and increase the probability of errors and work-related accidents.

The variability of manufacturing processes operators

For an effective user-centered design it is necessary to adequately consider the human variability in all the steps of a system development, not only taking into account the characteristics of most possible users'population in the initial stages of system definition and concept, but also using subjects representative of that variability in the testing phases on prototypes or on functioning systems.
Designers often would prefer to consider just "standard" persons, with certain characteristics and needs, as it is simpler to design products and systems for replicants all alike, which requirements can be easily defined.
A classic standardization case is observed in some organizational models, that sometimes claim to integrate ergonomics in manufacturing processes (Bruder *et al.*, 2009), but that often don't adequately care about the human variability.
Some examples are WCM (World Class Manufacturing) and ErgoUas (Ergonomic Universal analyzing system), methods of work rationalization that tend to eliminate the operations without added value, that hence can be canceled without impairing the production of the single workplaces, as walking, passing a tool from one hand to the other, laying it down, turning it upside down, etc. They present some positive aspects, as, for instance, they define the rest times of a working phase calculating the risk index of musculoskeletal disorders. For example, if a worker has to make unhealthy movements (trunk bending, applying forces by the hands, load lifting, upper limbs repetitive movements, etc.) ErgoUas system assigns an higher rest factor; if, vice versa, dangerous movements are unimportant, the rest factor is reduced. According to some trade unions, the work rhythms defined by that system take into account just movements harmful to health, but don't evaluate the fatigue caused, for instance, by standing still. Another troublesome aspect is the excessive standardization of the method, that doesn't consider the subjective needs regarding both postural attitude and cognitive load due to work rhythms increase. These aspects can be correlated, as, sometimes, people prefer to adopt irrational postures, but that help to relieve the psychophysical tension. In addition, it is often better to do useless activities, as walking, instead of doing repetitive tasks or maintaining fixed postures.
Another organization system is EAWS (European Assembly Work-Sheet) developed by the International MTM (Method Time Measurement) Directorat, that is a first level integrated system that allows to obtain an analytical measurement of biomechanical load of the whole human body in relation to postures, to forces, to manual material handling and to low loads at high frequency upper limbs movements.
Usually these methods take into account many ergonomic principles cited in standards and in scientific literature on postural and movements repetitiveness aspects, but don't consider adequately (Tuccino, 2010) the inter-subject variability, not only of their physical characteristics, as anthropometric dimensions or the ability to apply forces, but also of their motor and cognitive functions.

Human variability in manual handling of loads

Standards ISO 11228-1 (2003) and EN 1005-2 (2003), that specify ergonomic recommendations for the design of machinery involving manual handling of machinery and component parts of machinery, (including tools linked to the machine, in professional and domestic applications) takes into account gender and age differences. To define the safe maximum limit for the mass that can be manually handled without risks, the reference mass. is differentiated according to the intended user population. As underlined by Fallentin *et al.* (2001) these Standards are particularly design-oriented and represent an important improvement of NIOSH (Waters *et al.*, 1993) method, because they don't refer to a "general working population", but require the definition of an "intended user population" (elderly people, children, males or females, specialized working population, etc.) that may be exposed to different risk levels.

Human variability in everyday products design

Everyday products are generally addressed to an extremely various community and have to be easily used by people that present a wide range of characters, as anthropometric data, age, gender, abilities, nationality, cultural level. For an effective user-centered design it is important to clearly define these characters in the phases of system definition and conceptualization and to employ users' samples representative of all the predictable range in the testing phases (ISO 20282: 2006).
In some cases the users' group is a subsample of the general public, as, for instance, in the case of products used only by female subjects. It is interesting to point out that some design centers particularly advanced and focusing on users' needs and desires created communities as "Femm Den", that, considering that women buy or influence up to 80% of consumer goods, wants "to save good women from bad products" conceiving products that take care of women's characteristics and points of view.
If a product is marketed in various countries all over the world, it is necessary to consider the different characteristics of users of all that countries. No group has to be excluded and, if possible, it is important to take care also of disabled persons, applying principles of *Design for All.* Technological development allowed many people groups to overcome a number of previously encountered difficulties in various activity areas and to take advantages of particular abilities. Some examples are prosthesis, as eyeglasses, hearing aids, wheelchairs, and also Braille alphabet, computers and the Internet. Computers are an invention easy to use by people with a wide range of differences, such as with regard to language, disabilities, location and work habits. This is largely due to the fact that both the hardware and the software are extremely customizable

to accommodate a vast range of human differences and preferences (The Linux Information Project, 2005).
In general, the wider is the population under consideration, the more difficult is to find solutions satisfying most of that population, even if often differences between people within any given nation or culture are greater than differences between different cultures (Billikopf, 2009): persons of different countries show similar abilities operating on everyday products; main differences regard aesthetics, culture and language. Design must consider also the variability of cognitive abilities as knowledge, experience, cultural level, that can greatly influence the ease of use.
An interesting approach is offered by studies aimed to extend the concept of human-centered-design toward a goal of humanity-centered design (Sklar and Madsen, 2010), balancing the needs of the individual with those of community to find innovative solutions suitable to developing countries, considering the exiting context and infrastructures.
Recently in industrialized countries there was a remarkable growth of studies on products pleasantness (Jordan, 1999) and on the so-called *user experience design*, namely the creation of new interaction models between the user and a system (Norman, 1999; Paluch, 2006). These studies are oriented towards the systematic and scientific analysis of new products features and, particularly, of emotional and sensory aspects, as beauty (Hall, 2005), especially for interactive products (Hassenzahl, 2004). Many researches are done with a trans-cultural perspective related to globalization processes: in particular, the GLUE (*GLobal User Experience*) consists in examining both the differences and the similarities between users'groups of different geographic areas in terms of needs, desires, motivations, cultural models that can influence the user experience, situation in which the aesthetic pleasantness has an important role. The applications at the moment regard mainly websites design, that are transnational by their nature, but are expanding to all new technologies. Quite significant is the title of the 2010 International Conference of UPA (Usability Professionals'Association): "Embracing Cultural Diversity – User Experience Design for the World".
As quoted in Unesco Declaration (2001) cultural diversity is a "common heritage of humanity, as necessary for humankind as biodiversity is for nature": its defense is "an ethical imperative indissociable from respect for the dignity of the individual". "Creation draws on the roots of cultural tradition, but flourishes in contact with other cultures. For this reason, heritage in all its forms must be preserved, enhanced and handed on to future generations as a record of human experience and aspirations, so as to foster creativity in all its diversity and to inspire genuine dialogue among cultures."

References

Billikopf G. 2009. Cultural differences?, *Party-Directed Mediation: Helping Others Resolve Differences*, Appendix 1, http://cnr.berkeley.edu/ucce50/ag-labor/7conflict/14.pdf.

Bruder R., Rademacher H., Schaub K., Geiss C. 2009. Modular Concepts for Integrating Ergonomics into Production Processes". In: Schlick C.M., *Industrial Engineering and Ergonomics: Visions, Concepts, Methods and Tools*, Springer, 29: 382-394.

Contini B. 2003. *Prospettive di lavoro per gli anziani: una sfida per il prossimo decennio*. Laboratorio R. Revelli, Università di Torino, Working Paper n° 2,. http://www.laboratoriorevelli.it/_pdf/wp22.pdf.

Decreto Legislativo 9 aprile 2008, n. 81, Attuazione dell'articolo 1 della legge 3 agosto 2007, n. 123, in materia di tutela della salute e della sicurezza nei luoghi di lavoro.

EN 1005-2: 2003 - Safety of machinery - Human physical performance - Part 2: Manual handling of machinery and component parts of machinery.

European Agency for Safety and Health in Europe. 2007. *Expert forecast on emerging psychosocial risks related to occupational safety and health*", European Risk Observatory Report EN 5, http://osha.europa.eu/en/publications/reports/7807118.

Fallentin N., Viikari-Juntura E., Waersted M.N., Kilbom A. 2001. Evaluation of physical workload standards and guidelines from a Nordic perspective, *Scand. J. Work Environ Health*, 27, suppl.2: 1-52.
http://www.law.yale.edu/documents/pdf/Fallentin_EvaluationOfPhysicalWorkloadStan.pdf

Fubini E. 2010. *Ergonomia antropologica (vol. 2): Applicazioni agli ambienti di lavoro e di vita*. Franco Angeli, Milano.

Hall M. 2005. Is beauty the new usability attribute?, *UI Design Newsletters*, October 2005, http://www.humanfactors.com/downloads/oct05.asp#kath

Hassenzahl, M. 2004. The Interplay of Beauty, Goodness and Usability in Interactive Products, *Human-Computer Interaction*, 19: 319-349.

Herron R.E. 2006. Anthropometric Databases. In: Karwowski W., *International Encyclopedia of Ergonomics and Human Factors*, Taylor and Francis, 1: 243-244.

ISO 20282:2006, *Ease of operation of everyday products.*

ISO 11228-1:2003, *Ergonomics – Manual handling – Part 1: Lifting and carrying.*

Jordan P.W. 1999. Pleasure with products: Human factors for body, mind and soul In: Green W.S., Jordan P.W. (Eds.) *Human factors in product design. Current practice and future trends*, Taylor and Francis, London.

Meunier P., Shu C. Xi P. 2009. Revealing the internal structure of human variability for design purposes, Proceedings of the 17th World Congress on Ergonomics, August 2009,
http://people.scs.carleton.ca/~c_shu/pdf/design-IEA09-final.pdf.

Sklar A, Madsen S. 2010. Design for Social Impact, *Ergonomics in Design*, 18 (2), 4–5, 31.

The Linux Information Project, 2005. *Human Variability: A Brief Introduction.* http://www.linfo.org/human_variability.html.

Tuccino F. 2010. *World Class Manufacturing e sistema ErgoUas*, http://www.fiom.cgil.it/auto/fiat/materiali/10_09_10-saggioWCM_Ergouas.pdf.

UNESCO, 2001. *Unesco Universal Declaration on Cultural Diversity*
http://unesdoc.unesco.org/images/0012/001271/127160m.pdf.

Waters T.R, Putz-Anderson V., Garg A., Fine L.J. 1993. Revised NIOSH equation for the design and evaluation of manual lifting tasks. *Ergonomics*, 36,7: 749-776.

http://www.femmeden.com/about/.

http://www.fiom.cgil.it/auto/fiat/materiali/ergouas_fiat-A4.pdf.

http://www.mtmitalia.it/#.