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Evaluation of Human Cognitive Characteristics in Interaction with Computer

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1. Introduction

Research results from the past several years indicate significant influence of human-computer interaction (HCI) on computer system development, which, combined with technological development, enabled their application in almost every branch of human activity (Jacob et al., 2007). HCI can be defined as "a field of study related to design, evaluation and implementation of interactive computer systems used by humans, which also includes research of the main phenomena that surround it" (Dix et al., 1998).

Multidisciplinary nature of human-computer interaction requires contribution from different science disciplines, especially from computer science, cognitive psychology, social and organizational psychology, ergonomics and human factors, computer-aided design and engineering, artificial intelligence, linguistics, philosophy, sociology and anthropology.

Main goal of HCI is to improve interaction between the user and the computer in order to make computers more user friendly and designed systems more usable. Understanding physical, intellectual and personal differences between potential users defines the level of understanding and fulfilling user needs. Regarding different human perceptual, cognitive and motor abilities can lead to universally usable interface development. In HCI, knowledge of the capabilities and hitations of the human operator is used for the design of systems, software, tasks, tools, environments, and organizations. The purpose is generally to improve productivity while providing a safe, comfortable and satisfying experience for the operator (Helander et al., 1997).

In this Chapter, we have presented some new research results on HCI methodologies. An extension of cognitive model for HCI - XUAN/t, based on decomposition of user dialogue into elementary actions (GOMS) is described. Using this model, descriptions of elementary (sensor, cognitive and motor) actions performed by user and system are introduced sequentially, as they will happen.

In order to evaluate user performance in interaction with interface, based on the described model and psychometric concepts, we have developed software CASE tool for testing sensomotor abilities of user in human-computer interaction. Software CASE tool arranges tests into test groups for psychosensomotor and memory capabilities. Test construction is based on recognition of activities in user-computer interaction, prominent user characteristics and the measurement method of individual production results. Taking into account different aspects of user profiles confronts us with the challenges of physical, cognitive, perceptual, personal and cultural differences between users. Test concept allows program-led testing of the target group and precisely quantifies user performance. Every experimental result is just a piece of a mosaic in the human performance in interaction with information systems based on computers. User test results are persistently stored in a database and available for further statistical analysis. Case study is carried out using XUAN/t interaction model and supporting CASE tool with group of 234 users and the numerical results verifying the proposed model are presented in the Chapter.

The main research goal was suitability verification of different HCI techniques for special user groups. In this study we have obtained an efficient tool for making user profiles. The software tool enables graphical interpretation of the results, calculation of different statistical parameters, visual analyses of the tested groups averaged results and easy creation of the user profiles.

The Chapter is organized as follows. After short introduction, second section gives an overview of research results in the area of HCI related to our work. Our extension of the existing XUAN interaction model – XUAN/t model is described in third section while forth section explains details of testing methodology according to proposed model. The description of the software CASE tool we have developed in order to support the proposed model as well as description of several characteristic tests are given in fifth section. Obtained results of the case study we have carried out are given in sixth section, while the last, seventh section concludes the Chapter.

2. Related work

The most important element in HCI is user interface (UI). User articulates his requests to the system via dialogue with the interface. Interface is the point at which human-computer interaction occurs. Physical interaction with end user is provided using hardware (input and output devices) and software interaction interface elements. User interface, as an interaction medium of the system, represents "software component of the application which transforms user actions into one or more requests to the functional application component, and which provides the user with feedback about the results of its actions" (Myers & Rosson, 1992).

Key concepts of graphic interfaces are based on the WIMP metaphor, which includes key elements of the interface: Window, Icon, Menu and Pointer.

The importance of user interface and human-computer interactions was noticed in the late 1970ties. In 1982 this caused a development of an independent research group, which, in 1992, had formed HCI as a special discipline (Dix et al., 1998).

The subject of HCI research is human being and everything related to human being: work, environment and technology. Classification of HCI methodologies was made based on the method by which end user is incorporated into system development (Brown, 1997):

- *User centered development* - provides system development FOR the user based on feedback information from the user during the entire process of system development.
- *System development WITH users* – development of user participation which promotes system development in user environment (manufacturing facilities, offices, etc.) rather than within software companies.
- *System development based on taking the user into account* - this approach uses cognitive modeling of end users in order to understand user behavior in a certain situation and why one system is better than the other.

Cognitive modeling provides a description of user in interaction with the computer system; it provides a model of user's knowledge, understanding, intentions and mental processing. Description level differ from technique to technique and ranges from high-level goals and results regarding thinking about a problem all the way to the level of motor activities of the user such as pressing a key on a keyboard or a mouse click. Research of these techniques is done by psychologists, as well as computer science specialists.

Alternative cognitive abilities model, based on cortical functions, is also known as "simultaneous and successive syntheses model" (Das et al., 1975). In both information processing ways, simultaneous as well as successive way, the memorizing processes are integration core enabling functioning of the whole integration (including perception and cognitive processes).

Classification of cognitive models is based on whether the focus is on the user and its task, or on transformation of the task into interaction language (Dix et al., 1998):

- Hierarchical presentation of user's tasks and goals (GOMS);
- Linguistic and grammar levels;
- Models of physical level.

GOMS (*Goals, Operators, Methods and Selection*) (Kieras & Arbor, 1988) model consists of the following elements:

- ***Goals*** – are results of user's task and they describe what the user is trying to accomplish.
- ***Operators*** – are basic actions which the user must take while working with a computer system. Operators can act on a system (pressing a key) or on the mental state of the user (reading a message). Detail level of the operators is flexible and it varies based on the task, on the user and on the designer.
- ***Methods*** – are step sequences which need to be performed in order to reach a given goal. A step in the method consists of operators.
- ***Selection rules*** – provide prediction on which method will be used in reaching a given goal in case there are different methods to reach the goal.

Models of the physical level relate to human motor skills and describe user's goals that are realizable in a short time period. An example is KLM model (*Keystroke-Level Model*) (Card et al., 1980) used for determining user's performance with a given interface. In this mode, the task of accomplishing a goal is given in two stages:

- *Task acquisition*, during which user makes a mental picture of how to reach a given goal, and
- *Task execution* using the system.

Task acquisition closely connects KLM with GOMS level that gives an overview of the tasks for a given goal. KLM decomposes the phase of task performance into five different physical operators (pressing a key on a keyboard, pressing a mouse button, moving a cursor to a desired position, moving a hand from keyboard to mouse and reverse, and drawing lines using a mouse), one mental operator (mental preparation of user for physical action) and one system response operator (user can ignore this operator unless he is required to wait for system response). Each operator is given a time period for its action. By summing these time periods we get estimated time for completion of those tasks for a given goal. Precision of the KLM model depends on the experience of the designer, because he is required to make a realistic decision about the abilities of end user. Obviously, the development of high quality user interface is impossible without cognitive modeling and techniques.

Interaction models are descriptions of user inputs, application actions and obtained outputs. The models are based on formalisms, which ensure their implementation within interface development tools.
One of the oldest and most general interaction models is PIE model (Dix et al., 1998), which describes user inputs (from keyboard or mouse) and output to user (on a screen or a printer).
User Action Notification (UAN) model (Harrison & Duke, 1995) was developed by system designers in order to understand the complexity of interactions with regard to the system, rather than the user. UAN model efficiently describes (and identifies) four elements of interaction in a way understandable to all participants in software development. Also, it does not differentiate between text and graphic interfaces, thus supporting each interaction technique. A drawback of this model is its approach to interactions by regarding the system only, without taking into account the other participant, the human being. This problem was overcome in the XUAN (*eXtended User Action Notification*) model (Gray et al., 1994), which equally treats both the system and the user. XUAN model treats the user and the system in terms of their visible, in case of the user articulated, internal actions. The advantage of XUAN model is that it includes human mental action. Its drawback is excluding the state of the interface, which can lead to its inconsistency.

3. Extension of XUAN Interaction Model

In order to evaluate user performance as realistically as possible, we have extend the mentioned interaction models (UAN, XUAN). Our extended model - called XUAN/t (*eXtended User Action Notification per Time*) treats equally the complexity of interactions, both from the system and from the user. The proposed model is given in table form (Fig. 1), that is divided into two parts. The first part of the table contains two rows in which descriptions of the user`s mental or sensory as well as articulated or motor activities are given. The second part of the table contains three rows in which interface descriptions (visible actions and interface conditions) and internal system actions (core) are given. Separation arrow dividing these two parts represents a point at which human-computer interaction occurs, and it also represents a time scale. Activities are also presented graphically on the time scale. Graphic presentation also provides visual interpretation of position, order and duration of each activity.
With the aim to efficiently estimate the number of actions and time duration of the entire task, a complex dialogue is decomposed into elementary actions using GOMS model. Descriptions of elementary actions by the user and by the system are entered sequentially in order of occurrence. The time needed for completion of each activity is given. Estimated time is determined by summing the times required for individual activities. In this way, the proposed model provides interpretation of action descriptions with empirical variables, which can be evaluated.
In XUAN/t model, time component is based on the duration of individual elementary actions; it is limited by given events as reference points. The user initiates these events, but they occur in the system. The system can register them precisely in order to determine the beginning and the end of each activity. The model is intuitive and it can be easily supported with available software tools.

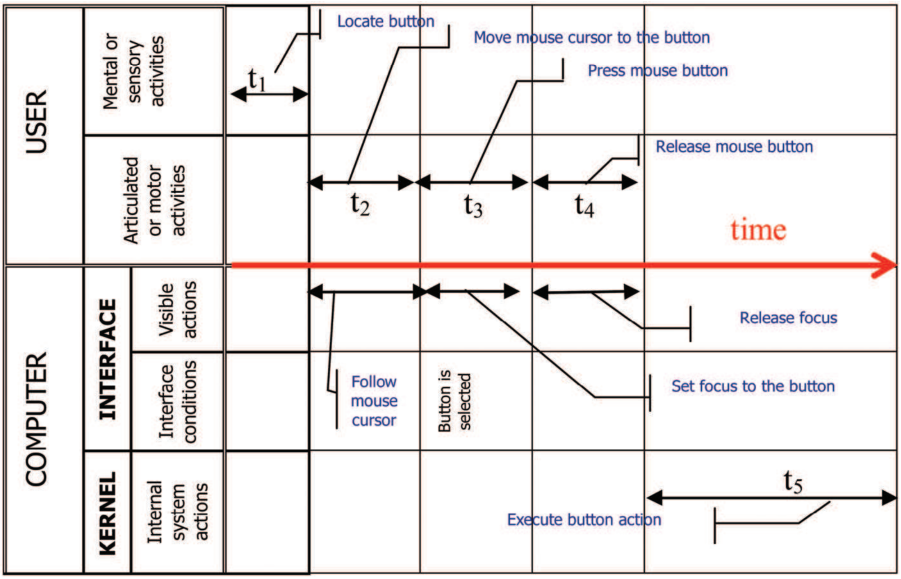


Figure 1. XUAN/t model of a click-on-a-program-field of the user interface

4. Testing Cognitive Characteristics Using XUAN/t Model

Understanding physical, intellectual and personal differences between potential users defines the level of understanding and fulfilling user needs. Regarding different human perceptual, cognitive and motoric abilities can lead to universally usable interface development. Taking into account different aspects of user profiles confronts us with the challenges of physical, cognitive, perceptual, personal and cultural differences between users.

A lot of tasks from everyday work are tightly bound to perception, so designers should be aware of the boundaries of human perception (Ware, 2001). The eyesight is especially important because the speed of human reaction depends on various visual stimuli, such as the time to accommodate to a very bright or very dim light, ability to recognize the appropriate part of a context, determine the speed or route of the moving point, etc. Visual sense reacts differently to different colors depending on spectral boundaries and color sensibility. The other senses, like these of hearing and touch, are also important.

The working environment can neither be ignored. Well-designed working environment increases user satisfaction, increases the speed of achieving the goal and reduces the number of errors. There is plenty of working environment aspects that should be taken into account such as: luminance level, albedo reduction, balance of light and glint, noise and vibrations, temperature, air flow and humidity, and the equipment temperature. Even the most elegant screen design loses its preference in noisy, dark and conglomerate environment. Such environment does not only reduce the working speed and increases errors, but also discourages even the most motivated users.

The classical methods of experimental psychology are under the constant development in order to cope with complicated cognitive tasks, specific to human interaction, on one side, and to computers on the other.

The reliable and valid results of the interface performance rating can be achieved by observing the user efficiency through the repetitive assignment of similar tasks in similar environment conditions.

The most important prerequisite to design an efficient interactive system is understanding of the user's cognitive and perceptual abilities (Wickens & Hollands, 2004; Ashcraft, 2001; Goldstein, 2002). Modern computer systems are based on human ability to fast interpret affection of sense organs and respond with a sequence of complex actions. In the short time intervals, (measured in milliseconds), users perceive changes on their screens and react adequately. The Ergonomics Abstracts journal (Ergonomics Abstracts journal, 2007) has published the classification of human cognitive process: short and working memory; long and semantic memory; problem resolution and reflection; decision and risk estimation; linguistic communication and understanding; search, pictures, and sensor memory and learning, skill development, knowledge acquisition and concept creation. That reference also specifies a set of factors which qualify users' perceptual and motoric performance: awaking and vigilance; weariness and the lack of sleep; sensor load (mentally); awareness of the results and loopback information; monotony and boredom; sense limits; healthy food and diet; fear, nervousness, mood, emotion; drugs, smoking and alcohol and physical rhythms.

According to the mentioned recommendations, we perform evaluation of user's cognitive characteristics by using specific tests designed for evaluation of certain characteristics and obtaining the user profile. Test construction is based on recognition of activities in user-computer interaction, prominent user characteristics and the method of measurement of individual production results. There are several steps during user-computer interaction, which we grouped into sensory, cognitive and motor activities.

Within sensory activities, we isolated the processes in which human being is gaining knowledge about phenomena and events around him such as:

- Impact of physical and chemical processes from the environment on human senses;
- Initiation of certain physiological processes in nerve cells of the sensory organs;
- Transmission of nerve excitation by neurons to the primary sensor zone in cortex,
- Initiation of a psychological response, which enables the human to become aware of the stimuli, which acted on the sensory organ.

In order to articulate his demands, user utilizes certain interaction elements of user interface (hardware and software), which enable his physical interaction with the computer. In physical interaction with hardware device, user makes a voluntary activity, which is coordinated with visual senses (from the primary sensory zone) and kinesthetic senses (from the motor cortex). Kinesthetic senses provide muscle coordination and development of skills for performing different complex movements while working.

Based on the described model and psychometric concepts, we developed software CASE tool for evaluation of human cognitive characteristics in interaction with the computer (Djordjević & Rančić, 2007).

5. Developed Software CASE Tool

In order to support new XUAN/t model, we have developed MS Access based software CASE tool that provides input of user identification data as well as user characteristics (Fig. 2). Using that tool, it is possible to determine the test list, and define general and particular test conditions.

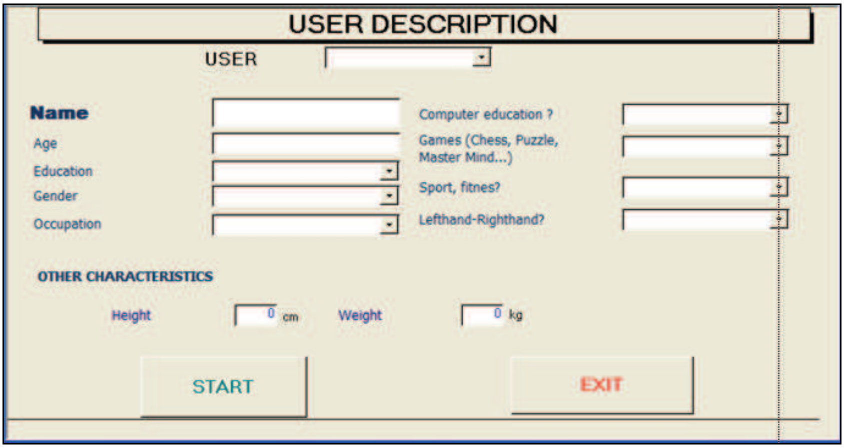


Figure 2. User description input form

In order to test all users under the same conditions it is necessary to define general conditions (screen resolution, mouse speed, etc.) and determine particular conditions of the micro surrounding (noise, light, temperature, etc.). During testing, tests are given in predetermined order with time limits. Testing depends on the choice of tests given on the list. Test groups related to perceiving, information processing and motor activities include tests of memory, sensory and psychomotor abilities.

5.1. Sensory Ability Tests

Cognitive processes, which represent response to specific stimulation, are represented using visual-information processing model (Atkinson & Shiffrin, 1968). According to that model, available information comes to special user´s sensory register and remains in it about one second. Physical characteristics of the stimulation are determined at this level. After that, information is erased from the register (has been forgotten) or transferred into the user´s short-time memory. At this level, some information has been lost, while the rest (along with information from user´s long-time memory) has influence on user response. The goal of sensory ability tests (perception) is to determine reaction times of users to visual (TP1) and audio (TP2) stimuli. User's abilities in domains of seeing, hearing and kinesthetic senses are tested. The test lasts 20 seconds, during which time user is stimulated with series of stochastic visual and auditory stimuli. User's task is to react as quickly as possible by pressing a certain key (LIGHT-OFF, RINGER-OFF), confirming registration of the tested stimuli. The CASE tool registers time lapse between giving the stimuli and user's response, as an evaluation parameter.

5.2. Psychomotor Tests

In order to articulate his demands, user utilizes certain interaction elements of user interface (hardware and software), enabling his physical interaction with the computer. In physical interaction with hardware device, user makes a voluntary activity, which is coordinated with visual senses (from the primary sensory zone) and kinesthetic senses (from the motor cortex). Kinesthetic senses provide muscle coordination and development of skills for performing different complex movements while working. The goal of psychomotor tests is

to determine the precision in coordination, object manipulation, psychomotor orientation, reaction time, manipulation aptness and the ability of making visual-motor guesses. First group of tests (PM), so called "CLICK-A-FIELD", is aimed to probing psychomotor orientation, visual-motor guessing ability and coordinated manipulation of user-computer interaction tools, coordination of individual senses and body parts. Tests last 20 seconds, and user's task is to click a field (1×1 cm), which cyclically, using random coordinate generator, appears on the screen. During the test, the software on-line continually registers times related to certain events (PRESS-MOUSE-BUTTON, RELEASE-MOUSE-BUTTON) and connects them in database with the user and the test. After the event, RELEASE-MOUSE-BUTTON field is erased from the screen and it appears at a new randomly generated coordinates.
In order to determine the influence of different factors on user's psychomotor characteristics we developed four different tests. The goals of these tests are the same, however: PM1 field on the interface is darker shade of gray than the background; PM2 field is highlighted red on the interface; in PM3 test the field is 1×3 cm on the interface; in PM4 test after RELEASE-MOUSE-BUTTON event a beep sound is given in order to provide audio stimuli.

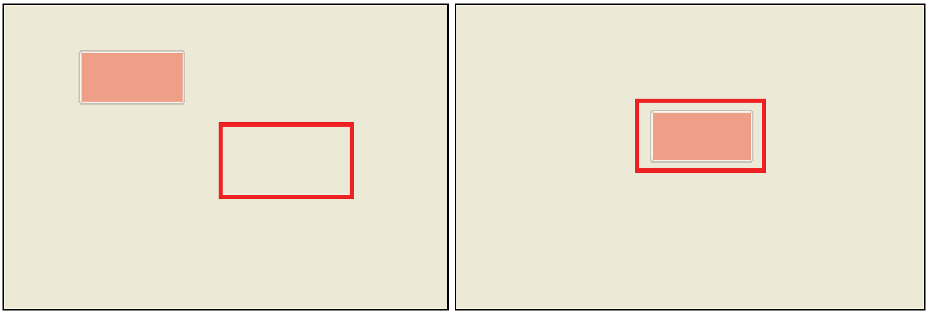


Figure 3. Test PM5 - "DRAG-ME" test

In order to determine precision and ability of fast, easy, correct and coordinated manipulation of visual objects with interaction technique of dragging objects on the screen, we have developed PM5 test (called "DRAG-ME") (Fig. 3). Test lasts 20 seconds, and user's task is to click on a red rectangular object on the screen and drag it into a rectangular window with red borders. After each attempt the object on the screen appears at a different randomly generated coordinates. The software on-line registers successful attempts.

5.3. Memory Tests

Memory is information-process structure composed from three components: sensory, short-time and long-time memory (Sperling, 1963). All memory components are necessary for successful information memorizing. Memory subsystem for sensory information deals with sensory representation of visual or audio event, which stimulates user sense during very short period. User´s short-time memory represents activity center in information processing system with limited capacity. In this zone, information comes from both sensory as well as user´s long-time memory subsystem (Sperling, 1963). Information in long-time memory is persistent with potentially unlimited capacity. Crucial characteristic of long-time memory is that information, which is memorized, may differ from the original information because of the user´s experience as well as other information influence.

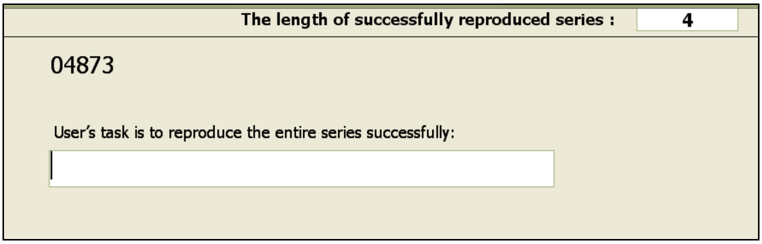


Figure 4. Test TM1: Memory test

The main goal of memory tests (TM1) is to investigate memory span through the ability of immediate reproduction of a series of elements after only one viewing of the series. This test is not time limited, it lasts until the first unsuccessful reproduction is made (Fig. 4). User can see, in a certain time interval, series of randomly generated numerical signs of given length.
Presentation time of the series is proportional to the length of series. User's task is to reproduce the entire series successfully. This step is repeated with each series one sign longer.
We have also developed two more tests with the same scenario as TM1 tests, with a certain difference: in TM2 tests, generated series are composed using letter signs only, while in TM3 tests, the series are composed using alphanumeric signs. The software CASE tool registers the longest length of successfully reproduced series as a memory span parameter.

6. Case Study

In order to acquire HCI ability information from different user groups, we have performed special tests on group of 234 users. The group includes n1=116 male and n2=118 female users. We have performed statistical analysis on obtained results in average reaction time on visual as well as audio stimuli in order to discover statistically significant difference between different user groups. For statistically significant difference estimation we used Student's t-test (Spiegel, 1992), which is based on average reaction time difference between two independent user groups (with limitation that n1+n2 should be greater than 60).

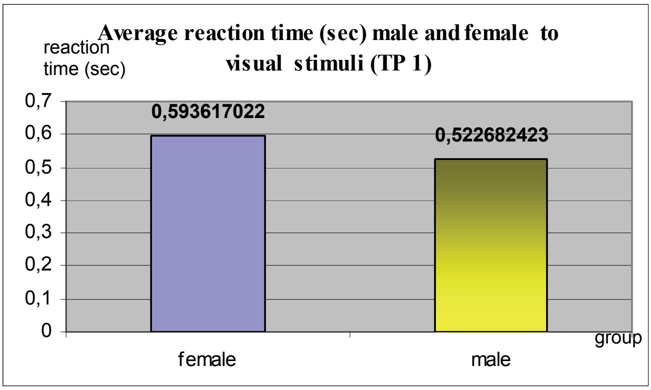


Figure 5. Average reaction time for male and female group in sensory ability tests (visual stimuli)

Hypothesis acceptance condition was that average reaction time difference between two independent user groups is significantly greater than standard average response time difference error. The standard average response time difference error for our test was 0.089419 sec. Obtained Student's t-value can be interpreted using Student's tables for limit t-values for chosen level of freedom n1+n2-2 (=232 in our case) and significant level (p=0.01, which means 99% of confidence).
In case of visual stimuli (TP1), obtained Student's t-value t=0.79 is less then limit value t=2.58, which means that there is no statistically significant difference between male and female users (Fig. 5). The difference is consequence of random variance, the samples belongs to the same basic set.

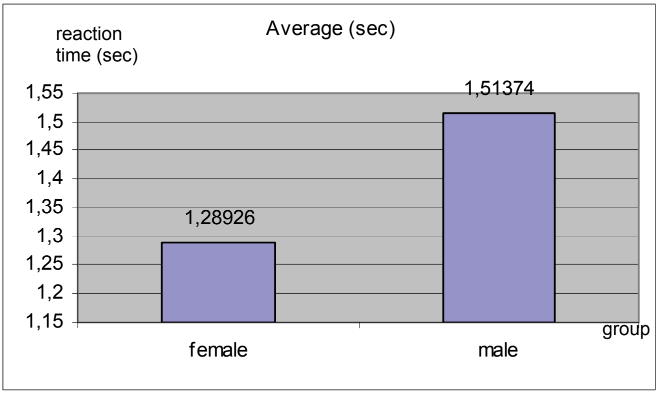


Figure 6. Average reaction time for male and female group in psychomotor ability tests (psychomotor orientation)

But, in the case of psychomotor orientation tests (PM), average response time was 1.51374 sec for male and 1.28926 sec for female users. Obtained t-value t=2.06 is greater than limit value t=1.96, which means (with 95% confidence, $p<0.05$) that there is statistically significant difference between male and female users (Fig. 6).

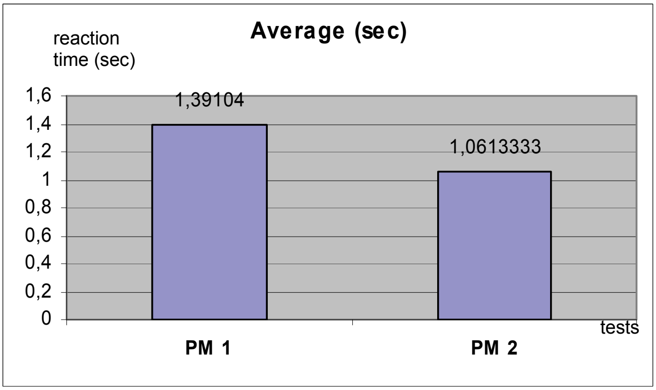


Figure 7. Average time in psychomotor tests with small and significant contrast difference in button color

Nevertheless, in case of psychomotor orientation tests with small (PM1) as well as significant (PM2) contrast difference in button color, average response time for entire testing population (both male and female users) was 1.39104 for PM1 tests and 1.06133 sec for PM2 tests. Since obtained t-value t=3.9567 is greater than limit value t=2.58, which means (with 99% confidence) it follows that there is statistically significant difference in response time between cases with small and significant contrast difference in button color (Fig. 7).

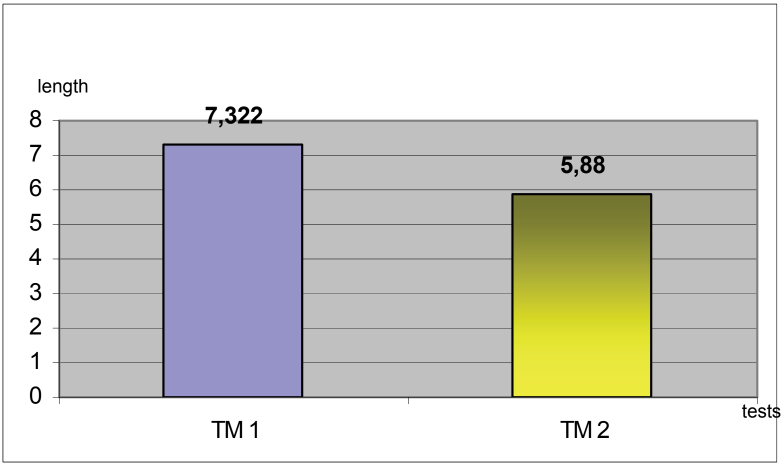


Figure 8. Average length of randomly generated signs sequence in memory tests

For the memory tests we used randomly generated numbers with average length of 7.322 numerical signs (for TM1 test) and randomly generated signs with average length of 5.88 letter signs (for TM2 test) (Fig. 8). Obtained t-value t=4.79 is greater than limit value t=2.58, which means (with 99% confidence) that there is statistically significant difference in average length of repeated sequence for numbers and letter signs.

7. Conclusion

Understanding physical, intellectual and personal differences between potential users defines the level of understanding and fulfilling user needs. Regarding different human perceptual, cognitive and motor abilities can lead to universally usable interface development. Taking into account different aspects of user profiles confronts us with the challenges of physical, cognitive, perceptual, personal and cultural differences between users. In order to evaluate user performance in interaction with interface, we extend the concepts of existing XUAN interaction model. Extended model is named XUAN/t and extension is related to the equal treatment of interaction complexity both from the system and user. Based on the described model and psychometric concepts we have developed software CASE tool for testing cognitive as well as psychomotor abilities of user in human-computer interaction. Test concept allows program-led testing of the target group and precisely quantifies user performance.

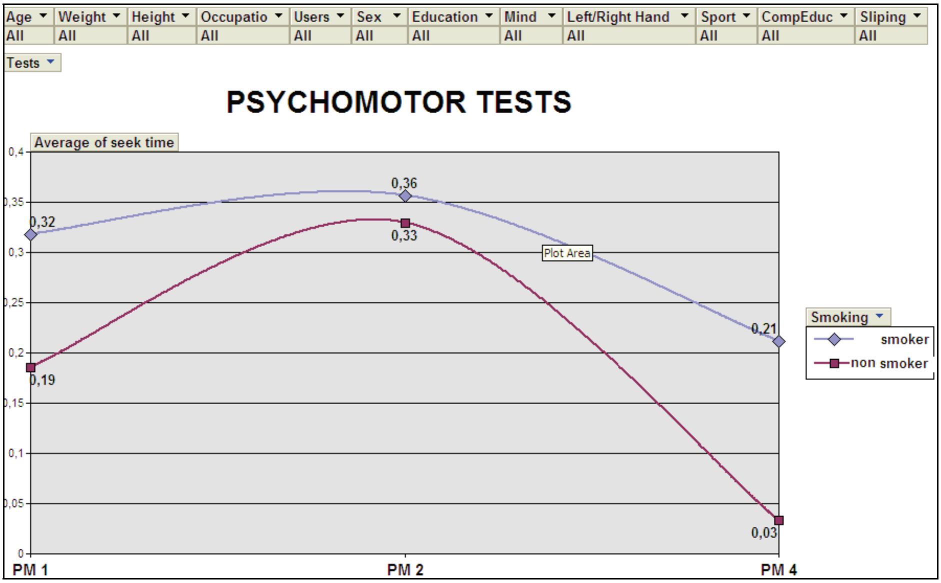


Figure 9. Graphical interpretation of user profile for smokers and nonsmokers

The developed software is efficient tool for making user profiles (smokers and nonsmokers, for example - Fig. 9). The software CASE tool enables graphical interpretation of the results, plenty of statistical calculations (Fig. 10), visual analyses of the tested groups averaged results and easy creation of user profiles.

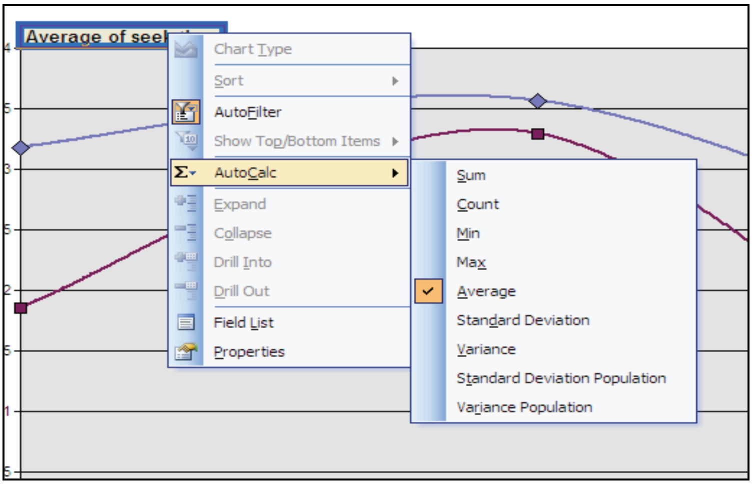


Figure 10. Set of the software CASE tool statistical calculations

In order to verify the extended interaction model (XUAN/t) as well as the developed software CASE tool, we have carried out case study for acquiring HCI ability information from different user groups. For this purpose, we have performed special tests on group of

234 users (116 male and 118 female users). Using our software tool, we have performed statistical analysis on obtained results in average reaction time on visual as well as audio stimuli in order to discover statistically significant difference between different user groups. Differentiation of tested users is utilized to determine compatibility of individual interaction models with given target groups. Qualitative analysis of obtained results provides recommendations for individual interface parts design suitable for the target group.
A future work should be based on extension of a set of user characteristics which qualify perceptual and motoric performance, as well as a set of tests using different interaction techniques. In that way we will obtain better software tool for reliable user groups profiling, enabling software designers to develop much suitable user interface for the chosen target group.

8. References

Ashcraft, M. H. (2001), *Cognition,* Third Edition, Prentice-Hall, Englewood Cliffs, NJ.

Atkinson R. C. & Shiffrin, R. M. (1968), Human Memory: a proposed system and its control processes, In: K. W. Spence and J. T. Spence (eds.): *The Psychology of Learning and Motivation*, vol. 2, New York, Academic Press, pp. 89-195.

Brown, J. (1997), HCI and Requirements Engineering - Exploring Human-Computer Interaction and Software Engineering Methodologies for the Creation of Interactive Software, *SIGCHI Bulletin*, vol. 29(1).

Card, S. K.; Moran, T. P. & Newell, A. (1980), The Keystroke-Level Model for user performance with interactive systems, *Communications of the ACM*, vol. 23, pp. 396-410.

Das, J. P.; Kirbi, J. & Jarman, R. F. (1975), Simultaneous and successive syntheses: An alternative model for cognitive abilities, *Psychological Bulletin*, 82, 1, pp. 87-103.

Dix, A.; Finlay, J., Abowd, G. & Beale, R. (1998), *Human-Computer Interaction*, 2nd ed. Prentice Hall Europe.

Djordjević, N. & Rančić, D., (2007), Software Tool for Evaluation of Human Cognitive Characteristics in Interaction with Computer, *Proceedings of the 8th International Conference on Telecommunications in Modern Satellite, Cable and Broadcasting Services – TELSIKS 2007,* pp. 446-449, ISBN: 978-1-4244-1467-3, Niš, Serbia, September, 2007.

Ergonomics Abstracts–the journal (2007): www.eee.bham.ac.uk/eiac/eiac7.htm

Goldstein, E. B. (2002), *Sensation and Perception:* 6th Edition, Wadsworth Publishing, Pacific Grove, CA.

Gray, P.; England, D. & McGowan, S., (1994) XUAN: Enhancing UAN to Capture Temporal Relationships among Actions, *Proceedings of the HCI'94 Conference on People and Computers IX,* pp. 301-312.

Harrison, M. D. & Duke, D. J. (1995), A review of formalisms for describing interactive behavior, *In the Software Engineering and Human-Computer Interaction – Notes in Computer Science*, vol. (896), Springer-Verlag, pp. 49-75.

Helander, M. G.; Landauer, T. K. & Prabhu, P. V., editors. (1997), *Handbook* of *Hurnan-Computer Interaction,*. Elsevier Science, Amsterdam.

Jacob, R. J. K.; Girouard, A., Hirshfield, L. M., Horn, M. S., Shaer, O., Solovey & E., Zigelbaum, J. (2007), Reality-based interaction: unifying the new generation of interaction styles, *Proceedings of ACM CHI 2007 Conference on Human Factors in Computing Systems*, vol. 2, pp. 2465-2470.

Kieras, D. E & Arbor, A. (1988), Towards a Practical GOMS Model Methodology for User Interface Design, In M. Helander*: Handbook of Human-Computer Interaction*, Elsevier Science Publishers B. V. (North Holland), pp. 135-202.

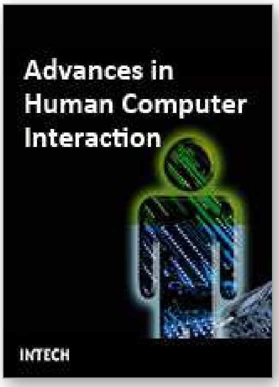
Myers, B. A. & M. B. Rosson (1992), *Survey on user interface programming*, In P. Bauersfeld, J.Bennett and G. Lynch, editors, *CHI'92 Conference Proceedings on Human Factors in Computing Systems*, pp. 195-202, ACM Press, New York.

Sperling, G. A. (1963): A model for visual memory tasks, *Human Factors*, 5, pp. 19-31.

Spiegel, M. R. (1992), *Theory and Problems of Probability and Statistics*, New York: McGraw-Hill.

Ware, C. (2004), *Information Visualization: Perception for Design,* 2nd edition, Morgan Kaufmann Publishers, San Francisco, CA.

Wickens, D. & Hollands, G. (2004), *Engineering Psychology and Human Performance*, Prentice-Hall, Englewood Cliffs, NJ.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