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DESIGN OF MEDICAL INFORMATION SYSTEMS USER INTERFACE

Abstract. The publication considers the relevance and purpose of medical information systems, as well as the tasks that should be solved by medical workers with their help. Functional capabilities and main modules of medical information systems were inspected. A list of the most powerful information systems is given, according to the recommendations of the Ministry of Health of Ukraine, for use in medical institutions. Since each medical information system has different modules with a unique interface, this requires certain skills to work with the system, understand the properties and principles of designing the user interface. The concept of the user interface is investigated, and its properties are specified. The main principles of the user interface design and quantitative methods of assessing its usability are described. Based on the result of the analysis, the strengths and weaknesses of methods for assessing the convenience of the user interface were identified. In particular, the complexity analysis method gives the possibility to investigate the actions and use of the system from the user's point of view, as well as the parameters that are responsible for the functionality of the system. It has been found that increasing the complexity of the interface leads to an increase in the number of operations that can be carried out in the medical information system. In turn, the use of the GOMS method makes it possible to evaluate the performance of the information system and step by step investigate its effectiveness, predicting the usability of the interface. On the one hand, a correct assessment of the interface complexity will make it possible to rationally adjust the process of the development of medical information systems on the basis of the user's previous skills. On the other hand, knowledge of the principles of designing the user interface and its properties will make it possible to effectively and fully use their functional capabilities in professional activities.

Keywords: user interface; design; medical information system; interface complexity; usability.

1. INTRODUCTION

Formulation of the problem. In Ukraine, since 2017, in the test mode, the Electronic Health System (eHealth) has been introduced, which aims to automate the maintenance of medical services and the management of medical data in electronic form. It consists of a central database and medical information systems, communication between which is provided using an open API (Application Programming Interface, a set of clearly defined methods for interacting various components), that is, determining the structure of data supply for exchange between software modules (complexes) and appropriate methods of processing them.

According to the Decree of the Cabinet of Ministers of Ukraine of April 25, 2018 № 411 "On some issues of the electronic health system", connection and exchange of data with the central database is possible only using a medical information system. A medical facility can select any medical information system from those that have been tested and connected to the central database. As of 2020, the Ministry of Health of Ukraine recommended the use of thirty-six such information systems. However, such numerous proposals can cause difficulties in the actual operation of medical information systems. Since each system has its own unique characteristics, functional modules, and continuous development, there arises the problem of standardization and evaluation of their quality.

The issues of user interaction with a specific medical information system, the complexity of its use, understanding of functional capabilities and the ability to navigate the interface are relevant for medical personnel. Each system has its own unique characteristics and functional modules, which must constantly adapt to current, at the time of application, versions of operating systems, communication equipment and specific new measurement devices. The need for continuous improvement of the systems can become a problem for the ordinary user, since using the API does not impose any requirements on the user interface, in particular, the use of forms and means of entering commands and data. A separate problem is the assessment of their quality and adaptability.

Analysis of recent research and publications. The features of the development of medical information systems and their characteristics were investigated in the works of S. M. Zlepko and T. I. Ovcharuk [1]. The properties and criteria of the user interface were investigated by M. Billinghurst, H. Gough, R. Green, L. Olfman, E. Raymond, J. Raskin, J. Satzinger, D. Sweed.

Among the most significant studies in the field of formation of principles of interface design are the works of T. Mandel [2], J. Nielsen [3]and N. Donald [4]. The principles of building the user interface of the cybernetic system are described in the work of I.I. Pasternak [5]. The works of Yu.I. Mashbitz [15], O.L. Wernik [16] are devoted to the analysis of the socio-psychological features of user interface design. Methods for assessing the complexity of using the user interface were studied by G. Bonsiepe [17], V.A. Zeng [18], S. Card [19], T. Comber [20], J. Maltby [21], T. Moran [22], A. Newell [23].

The purpose of the article is to highlight theoretical approaches regarding the design features of the user interface of medical information systems and substantiate methods for quantifying its complexity and usability.

2. RESEARCH METHODOLOGY

Theoretical and empirical methods of scientific research were used to perform the set tasks, namely: the method of system analysis, comparison and generalization for theoretical substantiation of methods for quantifying complexity and usability of medical information systems interface; bibliosemantic method – for studying psychological, pedagogical, and scientific literature, normative documents on the design of medical information systems; empirical methods – conversations with students and teachers, analysis of ways to use methods of diagnosing the usability of an interface and data analysis, obtained by timing the activities of operators (laboratory assistants and doctors) who worked with various software and hardware (measuring the time required performing cyclic operations in order to obtain data for such methods as assessing user interface complexity and GOMS); modeling – to investigate the method of assessing the user interface complexity of medical information systems.

3. RESULTS AND DISCUSSION

Studying the discipline “Medical Informatics”, future doctors form the skills in using medical information systems. The use of medical information systems is one of the components of the modern electronic healthcare system and makes it possible to fundamentally solve any problems that are traditionally described and based on this information array, that is, to move from simple search tasks to tasks that are associated with complex statistical and logical data processing. Search tasks include sorting and filtering data by a specific characteristic or characteristic group. Computational tasks include tasks to statistically process results and identify the relationship between parameters. The logical tasks include the tasks of diagnostics, prediction, determining the diagnostic value of signs and evaluating effectiveness.

The concept of “Medical Information System” (MIS) can be interpreted as a set of organizational and technical means for storing and processing data in order to ensure the automated operation of medical institutions with a central database. In the process of designing the MIS interface, the analysis of the activities of a medical worker is important and this is impossible without studying the question from the point of view of the user – what exactly should the information system perform? The important questions are: how will the data be entered into the information system and how will the initial data be presented to the user? It is worth noting that Ukrainian legislation allows the use of only those information systems that have passed the verification of the Ministry of Health of Ukraine and have been connected to the eHealth system. The web page of the State Enterprise E-Health [6] contains data on the modules and functionality that MIS should provide, in particular 8 modules with 16 different functions. The MIS modules include the following:

1. The administrative module of the provider of medical services of primary medical care – for concluding contracts and maintaining financial reports.
2. PMC doctor's workplace – to work with doctor's choice declarations, electronic medical records and electronic prescriptions.
3. The administrative module of the pharmacy institution is for registering pharmacies, their divisions and pharmacists.
4. Pharmacist's workplace – to work with electronic prescriptions under the program “Affordable medicines”.
5. The administrative module of the provider of medical services of specialized medical care is for registering the institution, its divisions and users.
6. SMC doctor's workplace – to work with electronic medical records, diagnostic reports and e-directions.
7. Patient Records Module.
8. Data access module.

By analysing the list of MIS recommended for use, one can distinguish those that ensure the availability of all functional capabilities, namely: “Dr.Elex”, “Clinica Web”, “Electronic Hospital 2.0”, “MEDICS IT”, “nHealth”, “SimplexMed”, “SimplexMis”. However, there might be cases when the MIS does not fully provide the necessary functions, or does not have the necessary module. In this case, it is planned to use modules of another MIS. Each medical information system has its own, unique interface, which requires work skills and understanding on the part of medical personnel. As an example, Fig.1 presents fragments of the user interface of the considered MIS.

According to the definition provided by the National Bank of Standardized Scientific and Technical Terms [7], the user interface is software and hardware tools for user interaction with automated systems (AS). There is also an interpretation of the “friendly” user interface

as interactive software tooling that provides a natural mode for the user to interact with information system.

Typically, when it comes to the use of automated systems for industrial purposes, the user interface is understood as human-machine interaction (general algorithm of AS development, operation and use, which ensures user interaction with AS). However, more often, the interpretation of this term is reduced to the concept of a "graphical interface" as an opportunity for the user to interact with the information system through a graphical embrace. In the Ukrainian library encyclopaedia [8], the "user interface" is interpreted as a means of convenient interaction of the user with the information system or a set of means for processing and displaying data that are most adapted for the convenience of the user.

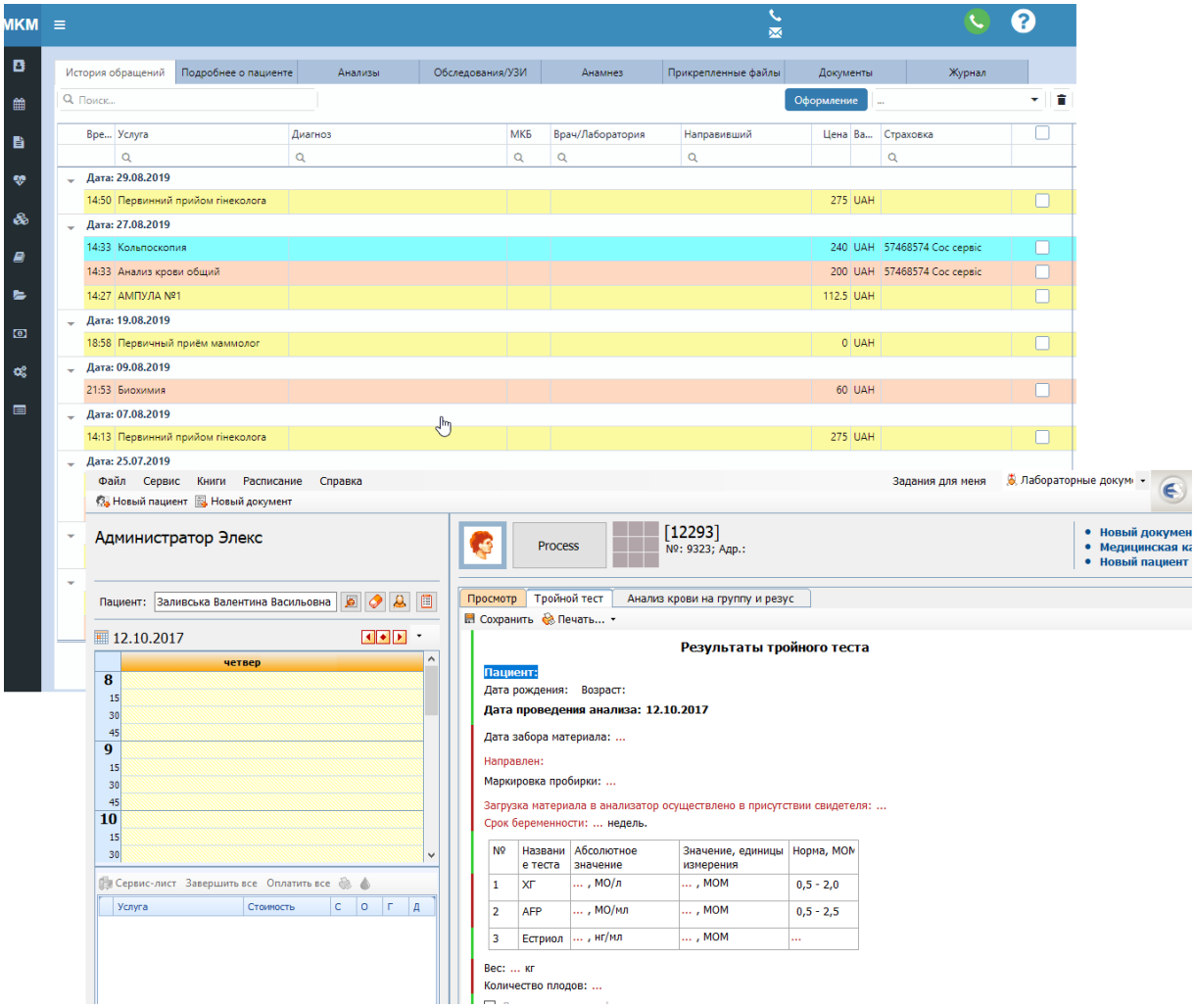

Fig. 1. MIS "Dr. Elex"and "Clinica Web"user interface fragments

The design and development of any interface is carried out to achieve certain aims and user tasks, so first you need to set the minimum amount of data that the user must provide to achieve them. The most cost-effective interface type will be one that does not require additional costs for searching, processing, and entering data and has the shortest time to complete a given task. However, these criteria, including performance reports, are not sufficient to objectively evaluate the quality of the user interface.

In the foreign [9], [10], [11], [12] and the domestic [13], [14] scientific literature, various properties that the user interface should have are investigated and described.

Table 1

User Interface Properties

№	Properties	Criteria
1	Clarity, clearness, readability	Avoidance of ambiguity in the interface, thanks to special use of language, hierarchy of elements and metaphors for visual elements
2	Compression, laconicism	Ensuring concurrent brevity and understanding of the interface without overloading the interface with excessive refinements and designations, with many elements on the screen
3	Familiarity	Use of associative examples from life to facilitate orientation in the interface
4	Adaptability	Provision of user feedback on the current state and success of data processing
5	Sequence	Coordination of the interface with software applications, which allows the user to recognize common schemes of operations
6	Aesthetics	Developing a visually attractive interface to impress a user with a certain kind of thoughts or feelings
7	Efficiency	Creating optimal conditions for user performance, taking into account the time spent until the desired result is obtained
8	Leniency, friendliness	Provision of interface flexibility to prevent user errors and give the ability to correct

It should be noted that the Ukrainian scientist Yu.I. Mashbitz initiated systematic scientific research into the psychological features of the construction of the human-computer interface [13]. The results obtained can be applied not only to systems intended for training, but also to the human-computer interface of any systems that provide for active (interactive) interaction of the user with the computer system.

The interaction between the computer and the user, that is, the exchange of actions and reactions to them, is divided into two types. The first type uses the command language – entering commands by text means, and the second – direct manipulation. A number of basic ways in which a user can interact with a computer can be distinguished, namely, the command language (the user controls the system by entering appropriate commands in text mode); dialog (when the system asks a question and the user answers); forms (user enters data in the corresponding fields); menu (the user is provided with a number of options and controls the system by selecting the necessary items); direct manipulation (the user controls the objects on the screen using the manipulator). The most ergonomic will be those information systems whose interface design takes a comprehensive approach in choosing how to interact. The ergonomic interface should ensure the display of data as efficiently as possible for human perception, systematize and structure them on the display in such a way as to highlight the most necessary.

The basic principles of building software interface are its understandability for a medical specialist, without additional long-term training. All controls must have names that are understandable to medical students. In the work [15], the authors analyse the psychological features of designing the user interface and propose to distinguish two of its basic components, namely, “informational” as an element of the information space and “natural” as an image of material or social objects. In particular, the essence of interface metaphors as a structure or organization of screen elements is disclosed, in which interaction with the information system is associated with a familiar situation and a role, which consists

in improving understanding of interaction semantics, provides a visual representation of dialog objects and determines a set of user manipulations with them.

In addition to these properties, there are also general principles for designing the interface. To understand how an effective MIS user interface should be built, let us consider these principles. The principle of the slightest surprise described in the work [16] is a general principle in the design of various types of interfaces and is applied to the design. It is based on the idea that the user can simultaneously pay full attention to only one object, it follows that the variety and novelty of the interface elements should be minimized. This principle is important for the current state of training students of any specialties, because everyone has some experience with gadgets.

The work [17] concludes that when two interface elements conflict or are ambiguous, their behavior should be that which will surprise the user the least. Since each user has their own expectations for a certain response of the information system, when designing its interface, it is necessary to avoid using objects that can cause ambiguity. The principles of "visibility" and "accessibility" highlighted in the work [18] and other publications on electronic educational resources can be extended to any interface. These principles can be used explicitly or indirectly also in the design of the MIS interface.

The principle of visibility (evidence) implies that in a good interface, all available functions must be visible so that the user is not distracted by additional and redundant information. This principle is based on the first signal system, with the direct influence of environmental factors (contemplation of the object or its model) on the user's receptors. This process takes place without, or with the minimum use, of verbal description. The principle of accessibility takes into account individual properties, indicating the need for strict compliance with the requirements based on the general psychophysiological characteristics of most people. Non-compliance with these requirements may hamper perception of all the details of the interface. This may be the reason for the inefficiency of the information system. Another principle that can be applied to interface design is the "skill formation principle". The assignment of the interface designer is to create conditions for building skills for its application by using elements that are in an effective range of visibility. The user receives information by visual and auditory perception and the constant use of the familiar interface forms a corresponding habit.

While developing an interface, it is appropriate to use the philosophical principle of Occam's razor, which states that one does not need to multiply entities unnecessarily. If you apply it to the user interface, you can draw the following conclusions:

- any task must be performed in a minimum number of steps;
- the logic of the actions should be obvious to the user;
- the user's cursor and eye path must be optimized.

The principle of 7 ± 2, formulated by J. Miller, is that a person's short-term memory can simultaneously accommodate no more than seven different objects, if there are more than seven, they are intuitively divided into groups, so the quantity of memorized items ranges from 5 to 9. However, the number of objects that are remembered depends on their complexity, the tasks associated with them and the time of their solution (Fig. 2).

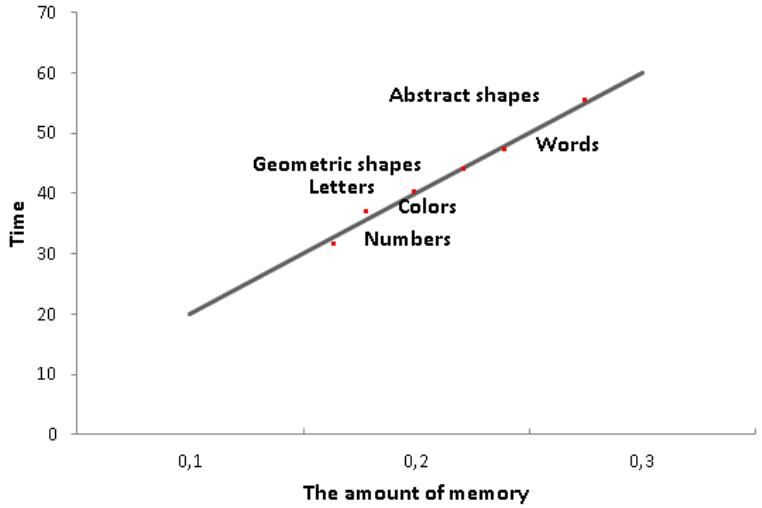

Fig. 2. Memory dependency on object complexity (by materials [19])

The principle of grouping is somewhat similar to the previous one, but the emphasis is on clearly dividing the screen into outlined blocks of elements that can be highlighted by the header for each block. In this case, the grouping should be logically meaningful. The principle of golden cross-section is also widely used when designing dialog boxes and controls of the information system. The principle of golden cross-section is considered to be the ratio that most fully corresponds to the aesthetic perception of the image and consists in the fact that two values form a golden cross-section if their ratio is the same as the ratio of their sum to the larger of the two quantities.

One method of diagnosing the usability of an interface is the method of analysing its complexity, which is offered by IBM user experience researchers [20]. This method quantifies and evaluates the functional tasks of the interface, taking into account the number of interface elements that prevent the achievement of the goal at each step of the task or during interaction with the interface. It is important to understand both the user and the expected outcome of the interface before performing a complexity analysis.

The main parameters that should be considered when assessing the complexity of the MIS interface are as follows.

1. Context shifts when the user navigates between graphical interface elements (dialog box, context menu, control panel, etc.);
2. Input parameters – the data that the user must enter to complete a specific action;
3. Navigation hints in the information system and steps to perform actions;
4. System feedback as the response of the information system to the operations that the user performs (event log);
5. Error feedback as the response of the information system to errors committed by the user;
6. New concepts – instructions on information system functionality or information that the user must learn to complete a specific action.

Each specified parameter has its own unique measurement scale, this is due to the fact that they have a different effect on the overall assessment of interface complexity. Three stages are distinguished when analysing the complexity of the interface. The first stage is a clear distinction between user tasks, individual steps, and interactions. A task is a separate component of a user's overall aim or work in progress, the user works to complete those tasks, and there is an interaction directly between the user and the item to complete the step.

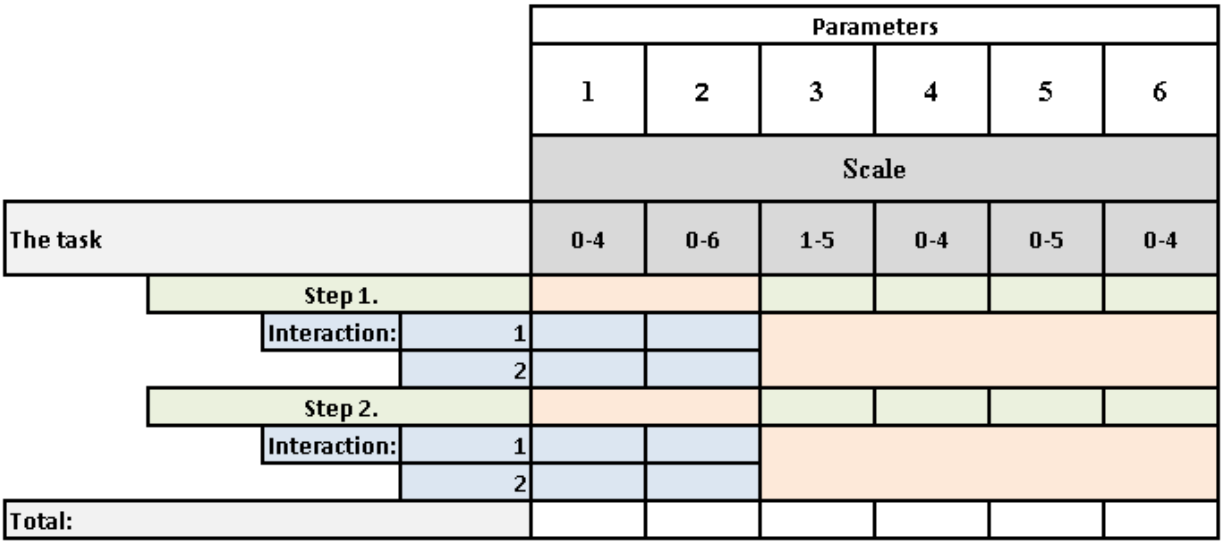

Fig. 3. Assessing user interface complexity

The second stage is evaluation of complexity of each step and interaction according to parameters. Parameters are evaluated by an expert group. Figure 3 shows an evaluation scheme and a scale, separately for interaction (r_i) and steps (S_i), which are analysed only by the first two parameters and the last four, respectively.

In our opinion, the usability of the user interface will be defined as:

$$U = \sum_{i=1}^{n}(S_i + r_i)\,, \qquad (1)$$

where S_i is the average estimate of all steps, r_i is the average estimate of all interactions.

The third stage is the analysis of the obtained numerical values and carrying out analytical and corrective measures. Complexity analysis not only identifies problematic interface elements, but also interprets those elements that are efficient and promising and have low complexity for the user. This is useful when designing a new information system interface. However, the proposed complexity analysis method makes it possible to interpret the final estimate only compared to another interface.

In the work of the German designer G. Bonsipe [21], based on the formula of K. Shannon (determination of the amount of data obtained at different probability of events), a formula is given to determine the complexity of the system. It can be applied to the definition of user interface complexity:

$$C = -N\sum_{i=1}^{n} p_i ld p_i, \qquad (2)$$

$$N = \sum_{i=1}^{n} n_i, \qquad (3)$$

$$p_i = \frac{n_i}{n}\,, \qquad (4)$$

where *N* is the total number of objects, *n* is the number of unique classes, n_i is the number of objects in the *i*-th class, p_i is the ratio of objects of the *i*-th class to all objects.

The method of dividing into classes is that the studied set is distributed into *n* classes and certain objects fall into one of them, it is believed that objects within an individual class are equivalent.

The work [22] described a relationship between complexity and usability of the interface:

$$U = f \cdot C, \qquad (5)$$

where *U* is usability, *C* is complexity of use.

In particular, authors conclude that the least and most complex interfaces are not well suited for efficient use. Analysing the schedule (Fig. 4), it can be stated that when the complexity of an interface decreases, it becomes more difficult for the user to recognize its various objects, but the interface becomes more predictable. The increase in complexity results in the user receiving more data, and hence more selection of operations that can be performed with the MIS. That is, the smaller the screen density (the amount of data showed on the display), the more accessible and understandable the data for the user, and vice versa, if the screen density is too high, this can lead to obstacles in assimilation and understanding of the data.

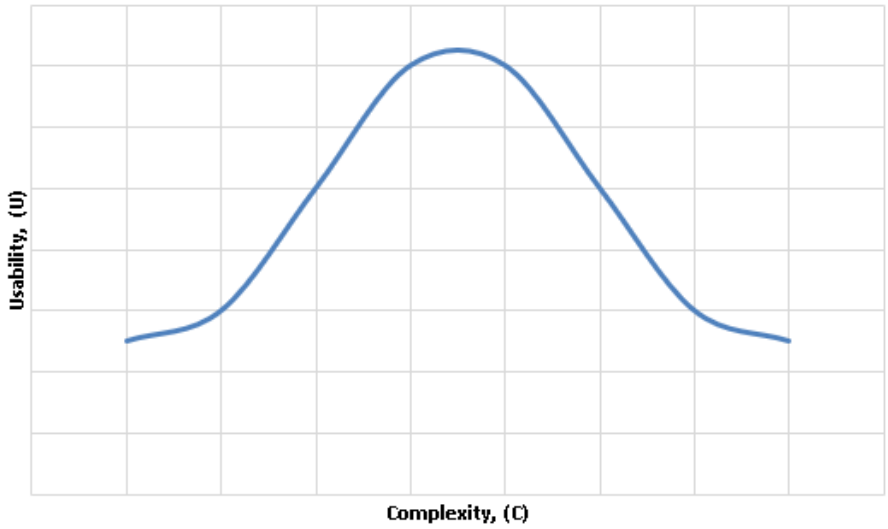

Fig. 4. Relationship between interface complexity and usability (by materials [19])

Another method applied to interface evaluation is the GOMS [23] method (from Goals, Objects, Methods, Selection rules – targets, objects, methods, and selection rules). Using this method, you can set the optimal time required to perform a specific action using a specific interface. According to the GOMS method [24], the time required for the system to complete a job is the sum of all the time slots that the system needs to perform a simple sequence of operations:

$$T = T_K + T_P + T_H + T_M + D + R, \qquad (6)$$
$$T_K = nK\,, \qquad (7)$$

where *n* is the number of manipulations; *K* – time required to press the button on the keyboard (0.8 s); *P* – time required to move the cursor to a certain place on the screen (1.1 s); *H* – time required to move the hand from the keyboard to the manipulator (0.4 s); *M* is the time required to consider the next step (1.35 s); *D* is the value of the linear function $D(n_d, l_d)$, the arguments of which are: n_d is the number of straight segments made by the manipulator, l_d is the total length of the segments; *R* is the system recall time.

The duration of different manipulations can vary considerably, but these values can effectively compare the interfaces and conclude that the interface can be faster. However, this method does not apply to the study of the system itself or its functionality and actions by the user, nor does it take into account random errors when executing tasks.

In the process of developing the skills in using MIS in medical students, first of all, it is necessary to pay attention to the complexity of the MIS interface; the obtained results of a preliminary analysis of its properties and parameters will make it possible to optimally adjust the learning path. Knowing the design principles of the user interface will give a possibility to correctly "place emphasis" when studying the structure and functionality of MIS. A structured view of how to interact with the information system and what to expect from it will have an unquestionable impact on overall performance.

4. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

The choice of a medical information system for training future physicians should be based on the criteria and principles of designing the user interface and depend on the complexity of its operation. The considered theoretical approaches should provide an understanding of the relevant user interface, and quantitative assessment methods – the ability to differentiate medical information systems by the complexity of interaction and the application of functional capabilities, the visual and rational component of the interface, the user's time consumption and the speed of the system. The results of our analysis identified the strengths and weaknesses of methods for assessing the convenience of the user interface. In particular, the complexity analysis method gives the possibility to investigate the actions and use of the system from the user's point of view, as well as the parameters that are responsible for the functionality of the system. It was confirmed that increasing the complexity of the interface leads to an increase in the number of operations that can be carried out in the medical information system. The GOMS method makes it possible to evaluate the performance of the information system and step by step investigate its effectiveness, predicting the usability of the interface. First, a correct assessment of the complexity of the interface will make it possible for developers to rationally adjust designing process of medical information systems based on the user's previous skills, second, it will give an opportunity for teaching staff to optimally choose the trajectory of shaping students' skills. Also, knowledge of the principles of designing the user interface and its properties will make it possible for students to effectively and fully use their functional capabilities in future professional activities.

During the study of computer science disciplines, namely in the performance of practical work, students of medical specialties are supposed to gain knowledge and master the skills in working in various MIS interfaces, which is essential for their future professional activities. The knowledge of the described approaches of design MIS interfaces are important for lecturers in the process of practical work with students of medical specialties.

The prospects for further research are the development of a methodology for formation of medical students' skills in the use of medical information systems and the creation of courseware based on interactive perception of the knowledge which is professionally relevant for medical students.

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ПРОЄКТУВАННЯ ІНТЕРФЕЙСУ КОРИСТУВАЧА МЕДИЧНИХ ІНФОРМАЦІЙНИХ СИСТЕМ

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Анотація. У публікації розглянуто актуальність та призначення медичних інформаційних систем, а також завдання, які мають вирішуватись медичними працівниками з їх допомогою. Проведено огляд функціональних можливостей та основних модулів медичних інформаційних систем. Наведено перелік найпотужніших інформаційних систем згідно з рекомендаціями МОЗ України для використання в медичних закладах. Оскільки кожна медична інформаційна система має різні модулі з унікальним інтерфейсом, це потребує наявності певних навичок для роботи з системою, розуміння властивостей і принципів проєктування інтерфейсу користувача. Досліджено поняття інтерфейсу користувача та конкретизовано його властивості. Висвітлено головні принципи проєктування інтерфейсу користувача та кількісні методи оцінювання зручності його використання. На основі результатів проведеного аналізу виявлено сильні й слабкі риси методів оцінювання зручності інтерфейсу користувача. Зокрема метод аналізу складності дає можливість дослідити дії та використання системи з точки зору користувача, а також параметри, які відповідають за функціональні можливості системи. Встановлено, що підвищення складності інтерфейсу призводить до збільшення кількості операцій, які можна здійснити в медичній інформаційній системі. Своєю чергою використання методу GOMS дає можливість оцінити швидкодію інформаційної системи та покроково дослідити її ефективність, спрогнозувавши зручність використання інтерфейсу. З одного боку, коректне оцінювання складності інтерфейсу дозволить раціонально скоригувати процес формування навичок застосування медичних інформаційних систем, а з іншого – знання принципів проєктування інтерфейсу користувача та його властивостей дасть можливість ефективно повною мірою використати їх функціональні можливості в майбутній професійній діяльності.

Ключові слова: інтерфейс користувача; проєктування; медична інформаційна система; складність інтерфейсу; зручність використання.

ПРОЕКТИРОВАНИЯ ИНТЕРФЕЙСА МЕДИЦИНСКИХ ИНФОРМАЦИОННЫХ СИСТЕМ

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Аннотация. В статье рассмотрены актуальность и назначения медицинских информационных систем, а также задачи, которые должны решаться медицинскими работниками с их помощью. Проведен обзор функциональных возможностей и основных модулей медицинских информационных систем. Приведен перечень самых мощных информационных систем, рекомендованных Минздравом Украины для использования в медицинских учреждениях. Поскольку каждая медицинская информационная система имеет различные модули с уникальным интерфейсом, это требует наличия определенных навыков для работы с системой, понимания свойств и принципов проектирования интерфейса пользователя. Исследовано понятие интерфейса и конкретизированы его свойства. Освещены основные принципы проектирования интерфейса пользователя и количественные методы оценки удобства его использования. На основе результатов проведенного анализа выявлены сильные и слабые стороны методов оценки удобства интерфейса. В частности, метод анализа сложности дает возможность исследовать действия и использования системы с точки зрения пользователя, а также параметры, отвечающие за функциональные возможности системы. Установлено, что повышение сложности интерфейса приводит к увеличению количества операций, которые можно осуществить в медицинской информационной системе. В свою очередь использование метода GOMS дает возможность оценить быстродействие информационной системы и пошагово исследовать ее эффективность, спрогнозировав удобство интерфейса. С одной стороны, корректное оценивание сложности интерфейса позволит рационально скорректировать процесс формирования навыков применения медицинских информационных систем, а с другой - знание принципов проектирования интерфейса пользователя и его свойств позволит эффективно, в полной мере использовать их функциональные возможности в будущей профессиональной деятельности.

Ключевые слова: интерфейс; проектирование; медицинская информационная система; сложность интерфейса; юзабилити.