Ergonomic Criteria for the Evaluation of Context-Aware User Interface

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***Abstract*— The need of a permanent and ubiquitous access to information is becoming increasingly apparent with the advent of new materials and the success of handheld devices. This led to the emergence of new paradigms in human-machine interaction, such as mobility and ubiquitous computing. The concept of user interfaces' adaptation has several facets. It requires a dynamic modeling approach. In this context, our paper is about designing an evaluation experiment for context-aware User Interface (UI). This evaluation is based on ergonomic rules proposed by experts. The non-contextualized ergonomics rules were adapted for the contextualized ones. In order to demonstrate context aware UI contribution, we chose to work on a critical area which is the medical field and especially on the diabetes disease.**

Keywords-Context-aware User Interface; User Interface Evaluation ; Ergonomic Rules.

I. INTRODUCTION

With increasing of devices' variety number and their use in ubiquitous environments by various types of users, user interfaces' adaptation has become a necessity rather than an option. Existing systems lack the ability to satisfy the heterogeneous needs of many users. These needs also vary according to the context, where context comprises of environmental conditions, the characteristics of device used to interact with the application, and the user characteristics. There is a need for techniques that can help the User Interface designer and developer to deal with a myriad of contextual situations. Also, the user should be provided with the facility to have an adaptive interface that adapts to changing user needs.

The final phase in the process of User Interface (UI) designing is the evaluation phase. Each created interface must be evaluated according to definite criteria. Several methods for user interface evaluation exist in the literature such as the work of Senach [1] or Grislin and Kolski [2]. However, we noted the scarcity or even the inexistence of those dedicated to contextualized interfaces.

In this paper, we propose an initial version of contextualized interfaces evaluation using some ergonomic criteria proposed specifically for non-contextualized interfaces.

We proposed in our recent works an approach for specification and generation of context-aware interfaces [3]. In this paper, we will evaluate the obtained interfaces. These interfaces are the interfaces of our application named DiaMon [3]. To test our approach, we propose DiaMon for monitoring of diabetic patients. Then, we conduct a statistical study with a medical team to evaluate our interfaces.

This paper is organized as follows: Section II discusses some literature reviews of interface evaluation approaches. In Section III, we present our approach. It is illustrated, in Section IV, with an application called DiaMon that concerns the monitoring of diabetic patients suffering from hypoglycemia in a smart hospital. In Section V, we propose the ergonomic rules for context-aware evaluation. Finally, in Section VI, we present our contextualized user interfaces used for the experimentation.

II. RELATED WORK

Several methods for evaluation UI exist in the literature. Senach [1] classified the interface evaluation methods into two types:

- Empirical evaluation methods (predictive): They are used to gather data related to user's behavior using the system. Such methods require a prototype or the real system.
- Analytical methods (experimental): they aim at evaluating the design of the system and not the usage. The use of abstract representations allows predictions of performance that cannot be performed in a purely empirical approach [1].

Grislin and Kolski [2] distinguish three main evaluation methods:

- The method centered on the opinions and/or user activities,
- The method centered on expertise. These approaches are based on the judgment of experts in Human-Computer Interaction (HCI) or on the evaluation forms or questionnaires classifying the qualities of an HCI.
- Analytical methods based on HCI modeling. These approaches are typically used to perform inspection using objective metrics from a human task model or a screen pages description.

In order to evaluate UI, some authors define some ergonomics rules. We can cite for example those proposed by Vanderdonckt [4] or Smith [5]. Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system. Through our study, we distinguish three types of ergonomics [6]:

- Physical ergonomics: represents the characteristics of human interaction with physical activity such as work posture, manipulation of objects, repetitive

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movements, arrangement of the workplace, the health and safety of the user.

- Cognitive ergonomics: is interested in mental processes involved in human interaction with the system components. It aims to analyze and verify the compatibility between the interface and the user.
- Organizational ergonomics: focuses on the optimization of socio-technical systems, which are composed of the organizational structure, processes, cooperative work, communication and resource management.

In general, the ergonomic knowledge is described as ergonomic rules used for the design and evaluation of interactive software.

In the literature, there is a great variety of ergonomic rules. To facilitate the use of ergonomic rules for designers, analysts and programmers, more research has focused on their classification in categories called ergonomic criteria.

Ergonomic guides were proposed. These include, for example Vanderdonckt recommendations [4], Smith [5] and Scapin [7].

Scapin and Bastien [7] proposed eight ergonomics rules: guide, workload, explicit control, adaptability, errors management, consistency/coherence, significance of codes and names, compatibility.

All these methods were used for non-contextualized interfaces evaluation. We combined several of these techniques in order to evaluate the contextualized interfaces. Before focusing on the resulting interfaces, we present in the following section, our approach to specification and generation of these interfaces.

III. Formal Approach for Specification and Generation of Conext-Aware User Interface

The objective of our research is to develop a global approach for specification and generation of context-aware interfaces in a medical field. Our methodology is based on the use of formal tools to cover gradually and consistently all stages, from the Human-Computer System (HCS) analysis and modeling to the generation of different graphic views.

The first step in our approach, shown in Figure 1, is the detection of contextual information. Once the data are received from the sensor layer, they will be modeled and decomposed into a user model (we model here the different user's profiles), a platform model (we present here the various platforms hosted on our application and exploited by different users); and an environment model (it describes the various environment characteristics such as geographical location, schedule, etc.). This decomposition is based on the definition proposed by Calvary et al., [8]. In parallel, the analysis of the HCS is necessary.

The second step consists in the user's task analysis specifying the sequence of actions to be performed. This analysis leads to the task modeling and the user requirements' identification.

The third step ensures the context and task modeling. This will be accomplished via the Petri Nets (PN) database that contains structures and elementary compositions of PN. PN were proposed by Carl Adam Petri in 1962 and were considered as a promising tool for task modeling [9]. PN are a mathematically based formalism dedicated to the modeling of parallelism and synchronization in discrete systems. PNs are continuously expanding and are a suitable tool for HCS modeling. Initially, they were only used to describe tasks that were computerized. However, later, especially with the emergence of High Level Petri Nets, they have been used to model Human-Computer Interaction [10]. Formal modeling of the Human-Computer Interaction, with Interpreted Petri nets allows the identification of all necessary user requirements in each point of interaction [10].

The fourth step ensures the detection of the user's current situation. It aims to identify the pair of (Context, Task). After a critical review, established in our last paper [11], none of the approaches gives full consideration to the user's activity or the task to be accomplished. Thus, we have associated the user task to its context of use. All couples "context, task" are therefore, previously stored in a database. At a given time, the status of different models determines the current context of the user (Ci). The identification of the adequate task Ti requires browsing the database "context, Task".

The fifth step provides the user interface specification. In this stage, user's requirements are identified in terms of interface's objects taking into account the ergonomic rules for the presentation of a mobile interface.

The last step in this approach is dedicated to the interface's creation. More details are presented in [3].

We consider our approach as a formal one because we used formal tools (Petri Nets) for the analysis and the modeling of contextualized user interface. The use of a formal method to describe the behavior of a context-aware system allows us to deduct the properties of the system and the users' requirements in order to generate the appropriate and valid interface at a given time.

After giving an overview of the advocated approach, we will present in the next section, our application called DiaMon.

IV. DiaMon: A Contextual User Inerface Assisting Medical Teams for Monitoring Hypoglycemic Patients

The overall objective of our application is monitoring diabetic patients in a "smart hospital". Equipped with biological sensors implanted under their skin, the system periodically checks the patient's Glucose Level (GL). Thus, it regularly observes the patient's status to alert by mobile devices the medical staff in case of an intervention.

The application is continuously connected to the monitoring system. While collecting information by the server, the system can, at any time, notices an unusual value of GL. That's why; an alert is displayed on medical teams' mobile devices. The user then has access to the patient's information for better intervention.

Several problems can arise from such an application. For example, in case of urgent and immediate intervention, how to alert the medical team and how to generate valid and significant interfaces guiding the doctor/nurse to fulfill their tasks?

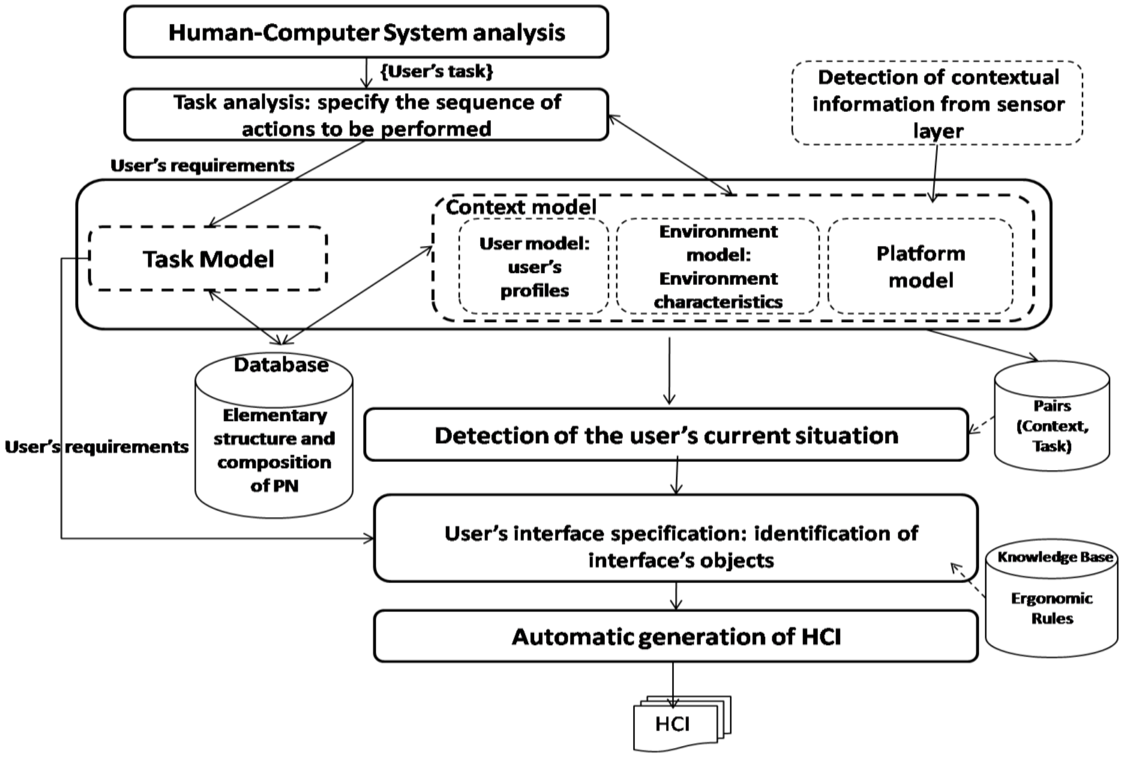

Figure 1. Proposed approach.

In case of hypoglycemic coma, how can we instantly notify those present in hospital to ensure a rapid intervention? And if the treating doctor is not present at the moment, how will the application interface adapt to the user's profile and his knowledge?

First, the application must identify the user's profile taking into account his knowledge in diabetology. Secondly, DiaMon has to detect the platform used to adjust and display the interface's graphical components. Finally, it must consider the environment in which the user evolves such as geo location and time response. Furthermore, the interface must adapt according to GL value. The graphical interface's components will change from one value to another. The originality of our application resides in the way it is designed to be used by all medical team regardless of their specialty or status (specialist, generalist, emergency physician or nurse). DiaMon fits to its context of use. It takes into account the user task, its environment, its profile and its level of knowledge. In addition, the user requirements are adapted continuously for each situation.

In this example, we are particularly interested in diabetes type 2.

For a patient with type 2 diabetes, there is a great risk of hypoglycemia. The latter represents an abnormally low sugar concentration in the blood. Hypoglycemia can result in a hypoglycemic coma that may cause the patient's death. We can recognize hypoglycemia through several signs: nausea, stomach cramps, palpitation, headache, tremor, etc.

Hypoglycemia may cause a hypoglycemic coma. This condition occurs due to a sudden onset of a state of agitation, muscle contracture, sharp reflexes and profuse sweating. Curative treatment of hypoglycemia depends on the patient's condition and his blood sugar. Two scenarios are possible: patient conscious or unconscious (Table 1) [12].

TABLE I. HYPOGLYCEMIA CURATIVE TREATMENT

Hypoglycemia with disturbance of consciousness	Moderate hypoglycemia
Condition : Blood glucose level between 0.3 and 0.4 g / l. Unconscious patient	**Condition :** Blood glucose level between 0.4 and 0.7 g / l conscious patient
Treatment: Slow intravenous infusion of 30 to 50 ml of 30% glucose solution, relayed by a slow infusion of serum 10% until patient wakes up. A slow intake of sugar (bread) is then recommended.	**Treatment:** Re-sugaring orally: 15g of fast sugar (3 sugar cubes diluted in water or juice) followed by a slow sugar intake (20g bread) Wait 15 minutes and repeat the Re-sugaring .

The two types of hypoglycemia treatment have a slow sugar intake (bread). In this case, we must consider the diabetics allergic to gluten (a substance into the bread). For this type of patients, it must replace the bread with gluten-free bread such as rice our, corn or buckwheat. A diabetic patient may be allergic to fructose. In this case, we must avoid the three pieces of sugar and fruit juice in case of moderate hypoglycemia. The sugar must be replaced by saccharin, aspartame, maltose or malt syrup.

Our approach resulted in a tool which produces contextualized interfaces. DiaMon provides adaptable interfaces to user profile and its current environment. The following stage is the evaluation of these interfaces. The problem with existing evaluation work is that they are primarily intended for non-contextualized interfaces. So, we have adapted those criteria to evaluate our interfaces.

The long term goal is to be able to propose new ergonomic criteria evaluation intended for contextualized interfaces.

V. ERGONOMIC RULES FOR CONTEXT-AWARE INTERFACE EVALUATION REGARDING NON-CONTEXTUALIZED INTERFACE

The evaluation of an interface is primarily intended to verify the reliability, quality, usability and usefulness of the HCI. The evaluation of the usefulness is demonstrated by answering these two questions: (i) Does the HCI meet the specifications? (ii) Can the users accomplish his task?

Concerning the usability of the HCI, it is verified by evaluating: (i) Efficiency: to achieve the expected result, (ii) User satisfaction, (iii) Ease of learning and (iv) Ease of use.

These parameters can be evaluated through an experimental evaluation (observation, data collection, interviews and questionnaires) or an analytical assessment (usage scenario and expert judgments).

In our research, experimental evaluation was conducted via questionnaire and analytical assessment was made via a scenario and expert questioning of the domain (pharmacists and doctors).

These evaluation criteria mainly concern the non-contextualized interfaces. We have noticed during this work the scarcity of ergonomic criteria for contextualized interfaces. However, some criteria proposed in the literature, have seemed interesting for the evaluation of dynamic interfaces. For example, we can mention the adaptability criterion regarding the ability of an interface to react depending on the context and the user's needs and preferences.

In order to assess the quality and the reliability of our interfaces, several measures criteria were defined. For clarity, we have broken our evaluation criteria into two sets: the observable and unobservable criteria.

A. Observable criteria

The observable data consist in what the subjects have been doing during the simulation such as selecting tabs, data entry or changing icons. We can also consider the simulation start or the elapsed time.

B. Non observable criteria

These criteria can be derived through interviews, questionnaires or other data collection techniques. For our work, we choose to use the questionnaire technique. The development of our questionnaire was governed by ergonomic rules proposed in the literature. These rules can be applied on contextualized interfaces.

We asked twelve participants to take part in the evaluation stage and go through the simulation platform then fill the survey. We have developed the interfaces of this scenario and we asked the participants to try them and answer the questionnaire.

The participants were from different backgrounds and different range of age and experience. Some of them were generalists; others were diabetologists (private and internal to Tunisian hospitals), an emergency physician and two pharmacists.

C. Ergonomics rules for context-aware user interface

We modified ergonomic rules for non-contextualized interface to make them relevant for contextualized interfaces. Indeed, the existing rules do not take into account the user‘s preferences, the environment in which he evolves and his current activity.

First, we are interested in the adaptability criterion, proposed by Scapin. The original definition of this criterion is as follows: “The adaptability of a system refers to its capacity to behave contextually and according to the users' needs and preferences. The criterion Adaptability is subdivided into two criteria: Flexibility and User Experience.”

We decomposed the adaptability into four criteria:

- Adaptation to the user profile: The user interface must automatically adapt to the user's profile;
- Environment adaptation: The user interface must adapt its content according to environmental data;
- Adaptation to the user’s knowledge: The user interface must identify the user's profile in terms of knowledge. It must provide the appropriate information to his level of expertise;
- User preferences: The user interface must adapt its content to the user preference.

Then, we focused on utility, ease of use, usability and the quality of UI criteria:

- Utility: The user should be able to accomplish its task using its interface. The interface must satisfy the user;
- Ease of use: The interface should be easy to use. It must be understandable and clear;
- Usability: The extent to which a UI can be used by users to achieve specified goals with effectiveness, efficiency and satisfaction;
- Quality: The information displayed in the interface must be relevant.

The criteria have been modified as follows:

- Utility of contextualized UI: The user should be able to accomplish its task using its interface and the UI should consider environment's changes. The interface must satisfy the user by automatically changing these components if the user’s task evolves;
- Ease of use: The interface should be easy to use for the user. It must take into account the user profile by adopting its components;
- Usability: The extent to which a UI can be used by users to achieve specified goals with effectiveness,

efficiency and satisfaction in a specified context of use. The user's goals can change according to the current environment, so the UI must change.

- Quality: The information displayed in the interface must be relevant, valid and understandable by the user. The information must be reliable and suitable to the display area of the mobile device.

All these criteria are used in our evaluation experiment, in order to evaluate the contextualized interfaces.

VI. EVALUATION EXPERIMENT

A. *Context-aware user interface for experimentation*

By applying our approach to our application, we were able to generate contextualized interfaces. This generation is done manually for the evaluation experiment. Following the application of our approach, we got the interfaces specification. These interfaces were the subject of an experimental study. The majority of user interfaces evaluation work is based on ten to fourteen participants. We have succeeded in our work to test these interfaces on twelve doctor and pharmacist users.

During the evaluation phase, we have set up a scenario that describes an emergency physician that rescues, in the ambulance, a diabetic patient with a hypoglycemic coma.

We are inspired by the principles and general criteria for ergonomic contextualized interfaces to produce an evaluation questionnaire for DiaMon produced interfaces.

The DiaMon first interface, shown in Figure 2, displays the patient's personal information, the type of intervention that can be committed, the patient's allergies and the glucose level. The information displayed to the interface is adapted to the users profile by indicating the most suitable intervention and patient's allergies; and the patient's status by indicating the GL.

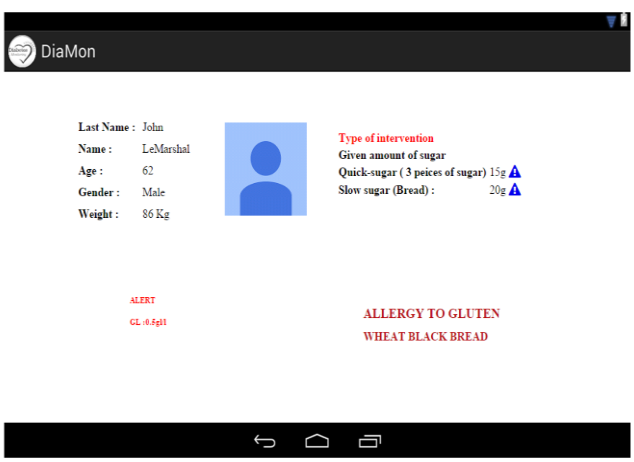

Figure 2. Initial patient status.

Once the patient glucose changes/increases, the alert message changes its position (displayed in the screen center), size and content. A message dialogue appears to alert the user to react (Figure 3). The interface's components change according to the environment's change. The alert and message dialogue adapts to this new situation (the change of Glucose Level).

Figure 3. Glucose Level change

When a hypoglycemic coma occurs, a new message appears announcing the patient's condition. The GL values change and the type of intervention is adapted (from a patient conscious to an unconscious patient (Figure 4)).

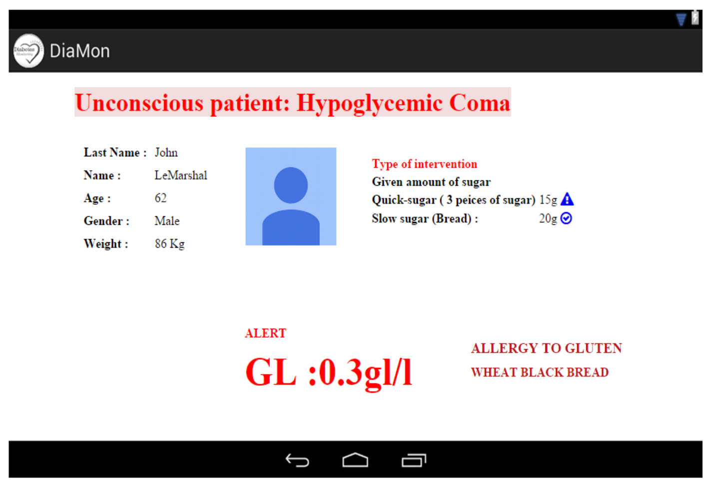

Figure 4. UI for unconscious patient

After testing our application, users answered a questionnaire. For more clarity and understanding; and in order to identify the exact view of our participants, we used the 4-point Likert scale [13]. Their responses were as follows.

B. *Results and analysis*

For the user profile adaptation, environment adaptation, adaptation to user's knowledge and user's preferences criteria, the following questions were asked:

1. Does the GL label's change help you for your intervention?
2. Is the appearance of the unconscious patient's label beneficial to you?

3. Does the appearance of gluten allergy's information help you to avoid making mistakes in your intervention?
4. Are the changes appeared in the interface beneficial for your contribution?

For the first question (Figure 5), eleven person of twelve have affirmed the usefulness of the occurrence of the label containing the glucose levels in the patient during the user's intervention.

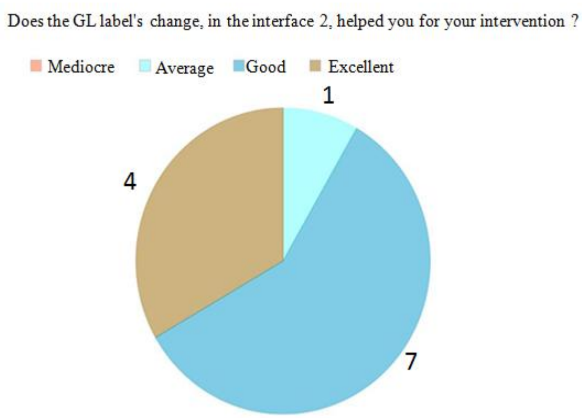

Figure 5. Appearance of GL label in the contextualized interface.

In Figure 6, over than 65% of the users found that the appearance of an alert about the fainting of the patient is excellent, while less than 25% found it good and below 5% said it was an average.

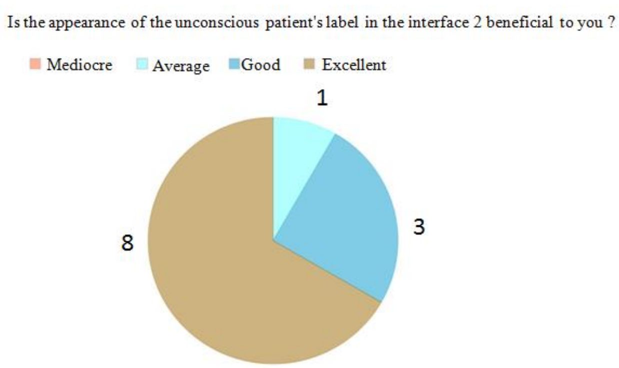

Figure 6. A question about the appearance of an alert message.

Regarding the question "what is the appearance of information "gluten allergy" was beneficial? 100% of participants affirmed that this information was necessary for the accomplishment of their tasks (Figure 7).

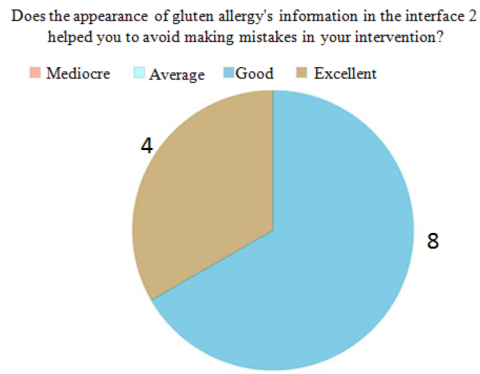

Figure 7. Appearance of information "gluten allergy".

For the last question, the majority (nine out of twelve) preferred the graphics components changes occurred in the dynamic interface. They have affirmed the advantages of the message appear on glucose levels and change of the intervention for the accomplishment of their tasks (Figure 8).

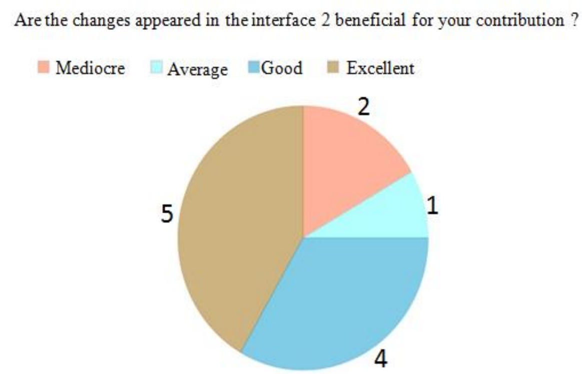

Figure 8. Graphics components changes in the dynamic UI.

For the ease of use and the quality criteria, the users' responses were as follows: the contextualized interfaces seemed to fulfill the participants' satisfaction with six out of twelve said it was good and three out of twelve said it was excellent as shown in Figure 9.

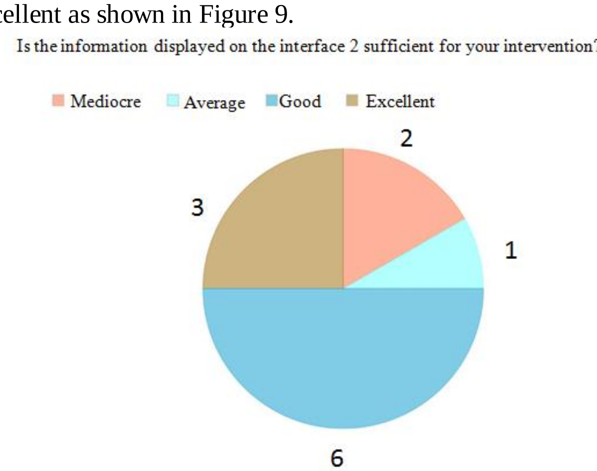

Figure 9. Information displayed in context-aware UI.

Through this study conducted with doctors and pharmacists, we confirmed that contextualized interfaces meet the ergonomic criteria listed above.

VII. CONCLUSION

In this paper, we stated some related work about existing UI evaluation methods and ergonomics rules. Then, we presented a formal and global approach for specification and generation of context-aware UI in six steps. We then presented our application named DiaMon, which is dedicating to health care staff to monitor their diabetes (type 2) patients' glucose level. This application was designed with context-aware user interfaces.

We also proposed ergonomic rules for context-aware evaluation where we modified some already existing ones and adopted them to the context-sensitive UI with respect to the HCI principles. Finally, an evaluation experiment was presented to apply our proposal to assess our Application DiaMon, and then followed by a statistical study to evaluate the contextualized interface.

In the near future, we will try to test our interfaces on more people and expand this study in order to develop clear and precise rules for the evaluation of contextualized interfaces.

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