Computer Methods and Programs in Biomedicine xxx (xxxx) xxx

Contents lists available at ScienceDirect

Computer Methods and Programs in Biomedicine

journal homepage: www.elsevier.com/locate/cmpb

Development and testing of iAware model for ubiquitous care of patients with symptoms of stress, anxiety and depression

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A R T I C L E I N F O

Article history:
Received 26 March 2019
Revised 7 August 2019
Accepted 2 October 2019
Available online xxx

Keywords:
Depression
Anxiety
Stress
Gamification
Biodata

A B S T R A C T

Background and Objective: This work proposes a model for ubiquitous care of patients with anxiety, depression and stress disorders using gamification and biodata, called iAware. Depression and anxiety are the most prevalent mental disorders, reaching million people worldwide. As they share many characteristics these two disorders can manifest themselves together. In addition, stress is one of the related factors with both depression and anxiety, being relevant in the analysis of these disorders. This work was carried out through a study on depression, anxiety and stress disorders (DASD), their treatments and the use of gamification as a means of engagement.

Methods: A/B tests evaluated with a clinical population the interaction engagement of the patient to the treatment provided by gamification. The iAware monitors and applies interventions for the patient at the most appropriate time, based on the patient's history. In order to evaluate iAware, six patients used a prototype with a smartband for two weeks. The patients also filled out a survey based on the Technology Acceptance Model (TAM). The survey was composed of 10 sentences and the results of each one are discussed.

Results: Interactions with intervention stages were greater in patients who used iAware gamified. The patients who used iAware got more occurrences of anxiety at home and in the afternoon and night. TAM evaluation showed that patients considered the use of iAware useful in their anxiety treatment routine.

Conclusions: The results pointed out that biodata is a supplementary alternative for DASD monitoring. In addition, the research work showed that the use of iAware for the support of anxiety treatment is useful for patients. Patients who used iAware without gamification did not perform or score the treatment activities. The evaluation showed evidence that the game improved the engagement of patients in the iAware use.

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1. Introduction

Depression and anxiety are the most prevalent mental disorders in the worldwide population [1]. Depression affects more than 300 million people, representing 4.4% of the world's population. Anxiety reaches more than 260 million people, representing 3.8% of the worldwide population. In Brazil, anxiety disorders are one of the most frequent psychiatric diagnoses in the general population. Data from the World Health Organization suggest that Brazil is the country with the highest rate of individuals affected by this disorder, with 9.3% of Brazilians being diagnosed, corresponding to 18,657,943 people [1]. These two disorders may manifest separately, however they often manifest themselves together [2], since they share many characteristics [3]. Stress is linked to depression and anxiety, so analyzing its relationship with these mental disorders might provide insights for mental disorder treatment [4].

As depression and anxiety disorders share characteristics, some types of interventions are used to treat both disorders. An example is the use of Cognitive-Behavioral Therapy (CBT) and the use of Mindfulness [5], these techniques are being automated through computation. Computerized interventions on health have grown

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https://doi.org/10.1016/j.cmpb.2019.105113
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due to factors such as the ease of information exchange via the Internet, the computers ability to be mobile, small and available in the environment in large numbers [6,7]. The advantage of these factors is presented in the intervention applied by Whale et al. [8] work, in which the benefits of data related to anxiety gathered through smartphone sensors are enlightened. This approach to computing is covered by ubiquitous computing [9], being applied in different areas such as commerce [10], education [11] and health [12], the latter also known as u-Health.

In this way, studies have shown that the use of fully automated self-help programs are commonly associated with low levels of adherence [13]. Therefore, programs designed as tools for use in psychotherapeutic treatment should consider user adherence as a form of reinforce bonding and remote support.

Based on the current trend, gamification has become a strategy to motivate and engage users in educational, business and health applications [14,15]. Gamification is the use of game dynamics and mechanics in computer applications to engage users.

Although the terms "dynamic" and "mechanics" of games are highly related, they are also used separately. The mechanics of the game relate to the gameplay, such as scores, levels, challenges and classification, while game dynamics focuses on results that the mechanics of the game offers, such as a sense of reward, achievement, competition, and altruism.

Considering u-Health for management of depression, anxiety, and stress disorders (DASD), smartphones and wearables are used in support to the prevention and management of these disorders due to their discreet use and their varied range of sensors [8,16]. These devices can monitor behaviors, aid in performing treatments, teach intervention techniques and also collect biological data such as the number of steps, heart rate and sleep quality [17].

Because depression and anxiety have affected more than 10% of the worldwide population, a lot of researches are conducted to improve the monitoring and treatment of these disorders.

For treatment to be more effective, patient engagement and adherence are paramount. This fact makes that research for improvement in DASD treatment promote these aspects through gamification techniques [8,16,18]. Another important aspect is to understand the right moment to do an intervention, thus bringing greater effectiveness to the treatment. One way to do an effective intervention is by analyzing the pattern of patient's physiological reactions, such as the number of steps taken, heart rate and sleep quality.

The physiological data or biodata when analyzed are indicative of symptomatic behaviors of a disorder, therefore this data type is relevant for applications for DASD interventions [19,20].

This article proposes a model to support DASD treatment through gamification and biodata, called iAware. The model monitors the users' actions and their physiological information (heart rate and quantities of steps) to apply interventions in a most opportune moment. The gamified interventions aim to promote patients engagement and adherence in DASD treatment [8,16,18], as indicated by their health professional.

The remainder of this article will first introduce the method used in this work in Section 2. Section 3 presents the results of iAware evaluation. Finally, Section 4 discuss the results, presents the conclusions and indicates directions of future works and Section 5, presenting the ethical statement.

2. Method

The method applied in this research was composed of three stages. First, the scientific contribution was identified through a search and comparison of related works. Then, based on this study, iAware was modeled with a focus on the scientific contribution identified. The last step was the implementation of a prototype and its application with patients to evaluate the feasibility of the proposal. The next subsections describe these steps.

2.1. Related works

The related works were selected through a systematic mapping study [15]. The search string was created from the terms "gamification", "depression" and their synonyms. This string was inserted into eight scientific repositories, including the Journal of Medical Internet Research (JMIR), PubMed Central, ACM Digital Library, Google Scholar, IEEE Xplore Digital Library, Science Direct, Springer Library, and Wiley. The general question "How gamification is being used to support mental health?" from systematic mapping study resulted in five papers focusing on the use of u-Health to support DASD management activities, and the work Hígia [21] was added by heuristics due to its relevance to this study.

Wahle et al. [8] present a Mobile Sensing and Support (MOSS) context-sensitive system for detecting depressive symptoms and providing interventions to those using the system. The detection system is based on the daily behavior of the patient mapped through the common sensors available on a smartphone. For the MOSS evaluation, 129 non-clinical people and over 18-year-olds started the evaluation program, but only 28 completed and served the system analysis. As results obtained from the evaluation, the system maintained a higher adhesion rate than other Android applications and it was able to offer the interventions in a dynamic way based on the need of each specific patient identified by the Patient Health Questionnaire (PHQ-9).

Ahtinen et al. [16] propose Oiva, a mobile application for stress management and depression. Oiva is based on acceptance and commitment therapy, contained in CBT. This therapy aims to develop commitment actions in the patients to deal with unexpected events, based on patients personal values. The Oiva offers mindfulness exercises to be executed within 1–3 min, wherever its users are. In order to motivate the engagement, the system used gamification, such as the progress in the CBT activities. Fifteen non-clinical volunteers evaluated Oiva, using the application in their daily activities for a month. The results show that the application was able to improve and support the well-being of Oiva users.

Bolier et al. [22] present a positive psychological online intervention (Psyfit), aiming to show a significant increase in well-being and reduction of the symptoms of depression and anxiety in the second and sixth month of treatment when compared with a control group. It also assess whether there are different levels of adherence in certain subgroups. To evaluate the Psyfit 284 patients with depression (mild to medium, evaluated by CES-D) were selected and divided into two groups, one using Psyfit and the other not. The results of the second month using the system showed that those who had used the Psyfit reached a significant improvement in their level of general well-being using the measure (WHO-5) than those who did not use the system. And through the MHC-SF measurement was identified a non-significant improvement in the level of well-being between both groups. The subgroup with a higher level of schooling had greater effects when analyzing the well-being and the depression, using the measure (WHO-5).

The work of Watanabe et al. [23] describes an application based on the TK manual called Kokoro-App, kokoro in Japanese means mind or heart. They aimed to look at the effectiveness of a smartphone-based CBT program for antidepressant replacement compared to a control group of patients suffering from depression using only antidepressants. Interventions consisted of eight sessions, one introductory session, two self-monitoring sessions, two behavioral activation sessions, two cognitive restructuring sessions and one completion session. The application design allowed patients to complete all sessions in at least 7 weeks, patients needed to complete tasks to advance to next sessions. The sessions are of average duration, requiring about 30 min to complete. The application has a reminder system that notifies the user by email to encourage him to complete the session and the duties. At the time of this research there was no information about the Kokoro-app evaluation results.

Paim and Barbosa [18] present Octopus, a model that explores gamification to stimulate the use of context-sensitive resources to aid in the ubiquitous care of non-communicable diseases (NCDs). This work is identified as related since studies show that depression at a medium-severe level could be categorized as a chronic disease or condition [24,25]. The Octopus used the gamification for the patient to engage in the use of health resources. The designed system works with any type of NCDs and used contextual history, allowing generate score and awards related to the use of health resources. The evaluation was through simulation of scenarios, where two patients walked on a virtual map. The patients could seek for the resources in order to complete activities on their current or near location. Through this evaluation it was showed that the Octopus is generic, supporting different NCDs.

Petry et al. [21] propose a ubiquitous model for caring people with depressive disorders, called Hígia. This model used a context history to assess whether a patient was having depressant signs and notified the accompanying health professional or caregiver. Hígia was based on modules, agents and has a specific ontology of depression. Hígia does not apply interventions such as the other works presented, but it monitors specific behaviors of each patient and its notification system informs caregivers any detection that needs an intervention. The model evaluation occurred in a prototype application by 7 non-clinical people and 5 psychologists for 7 days. At the end of the prototype usage, the users answered a technology acceptance questionnaire (TAM). The results obtained were favorable according to the utility and ease of use, both from the point of view of the patient and the psychologist.

To analyze and compare the related works, the essential characteristics of the ubiquitous care model design were identified. The characteristics were based on works for ubiquitous health care [6,26,27], in which context history, profiles, agents and ontologies are trends and strategic criteria. The criteria are considered present in the models when quoted clearly or when detected relevant indications of their presence. The comparison criteria are:

- Mental disorders: This item identifies the mental disorders that the works want to treat;
- Gamification: This criterion aims to find if the work uses gamification in its structure, to increase the engagement in the system usage;
- Mobile device: This item aims to identify if the works have a form of access to the user in a mobile device, allowing its use at any time that the user needs;
- Context: This characteristic identifies if the works use the context history feature, storing user information in a certain period. Any feature that stores a history of events and that is later used for inference, fits this feature;
- Profiles: This item aims to find if jobs use profiles to customize the user experience [28]. The use of resources that group characteristics and unique information of the user, contemplate this item;
- Agents: This characteristic identifies if the work uses agents for monitoring behaviors, context data analysis or to perform interventions;
- Biodata: This criterion aims to find if the work has some collection of biological data such as heartbeats, number of steps, quality of sleep, among other data that the patient's body can inform to;
- Modular: This item identifies if the work has some extension method of modules, being able to add resources or new competences;
- Notification: This criterion aims to find if the work has some way to alert the patient, or another user, to help him in the treatment. This feature lists the notification types.

Table 1 presents a comparison of the main features contemplated between the related works and iAware.

The **mental disorders** found in the related works aimed at treating anxiety, depression and stress disorders, being only the Octopus a generic model for chronic diseases, which also includes depression.

Gamification was used in most related works to keep the patient engaged, encouraging him to use the system. With exception of Hígia, all the works studied have at least one gamification feature. The found resources were scores, levels, dialogues and rewards.

The criterion **mobile device** was analyzed in the works evaluating if the system design was available through a mobile application, being able to need or not of the Internet. Access through a mobile device is important both to monitor behavior and to offer intervention in a more agile way. From the studied works only Psyfit did not offer this characteristic.

The **user context** was analyzed in the studied works and this resource was noticed only in systems that somehow monitored the patient. This finding is consistent, since the context history [10,26,29], allows mapping of the behavior of the patient helping to predict if he is presenting some symptom related to his disorder. The works that used context were MOSS, Octopus and Hígia.

The criterion **profile** was identified in three studied works (MOSS, Octopus and Hígia), which did some form of personalization to patients in the systems.

Agents were found only in two works (Octopus and Hígia), it shows that this resource has not been explored in the others studied works.

The use of **biodata** has become possible, given the increasing use of wearable devices [30]. These data allow systems to have more predictive power since the patient's body manifests the symptoms even before the patient be aware of them and tell these feelings to the system. This allows a more proactive mode of the system. None of the related works used this type of information.

The **modular** characteristic allows systems decentralization and extension. Thus, the system could be improved through new perceptions, allowing new integrations. From the related works only the Octopus and Hígia presented this characteristic.

The **notification** feature was identified as alert and email. From the studied works, only Psyfit and Hígia have at least one form of notification.

All items compared (column characteristics of Table 1) are found in at least one studied work, but no work has supported all items simultaneously. The use of biodata in patient monitoring was not explored in the studied works being present only in the iAware model. In general, the works focused on interventions and monitoring, many using sensors available on smartphones. Through the systematic review two major gaps were found, the first was on the effectiveness evaluation of gamification in DASD treatment and the second in biodata usage for monitoring the patients.

2.2. iAware model

The iAware is organized into component groups, these being modules, agents, applications and ontology. Fig. 1 presents the overview of iAware, showing its components and how they communicate.

Table 1
Related works.

Characteristics	MOSS [8]	Oiva [16]	Psyfit [22]	Kokoro-App [23]	Octopus [18]	Hígia [21]	iAware
Mental Disorders	Depression	Depression and Stress	Anxiety and Depression	Depression	Chronic Diseases	Depression	Anxiety, Depression and Stress
Gamification	Yes	Yes	Yes	Yes	Yes	No	Yes
Mobile Device	Yes	Yes	No	Yes	Yes	Yes	Yes
Context	Yes	No	No	No	Yes	Yes	Yes
Profiles	Yes	No	No	No	Yes	Yes	Yes
Agents	No	No	No	No	No	Yes	Yes
Biodata	No	No	No	No	No	No	Yes
Modular	No	No	No	No	Yes	Yes	Yes
Notification	No	No	Email	No	No	Alert and email	Alert and email

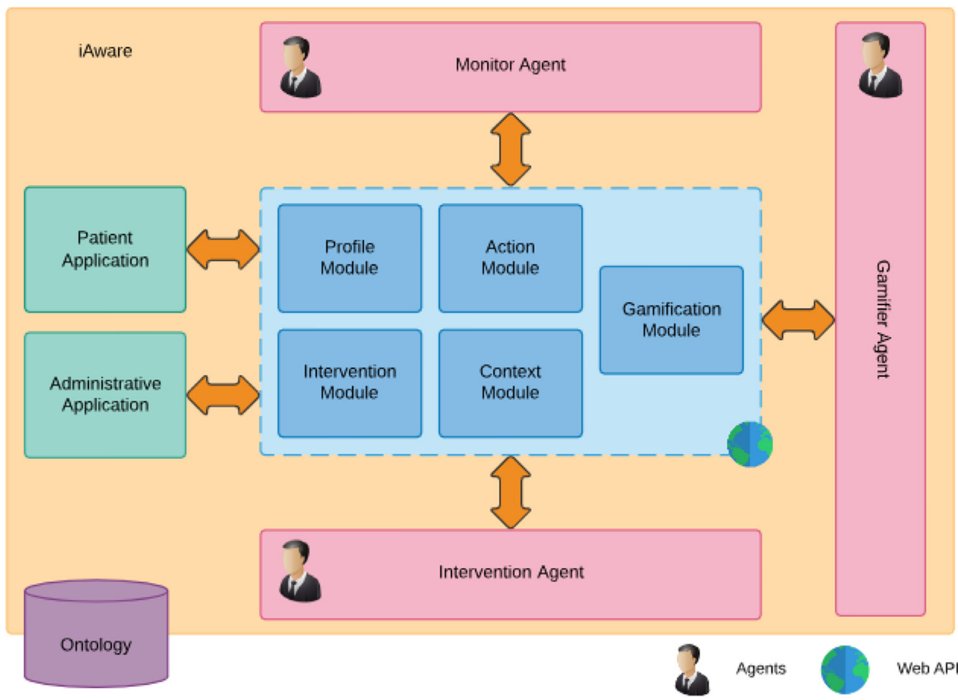


Fig. 1. Model overview presenting the interactions between agents, modules and applications.

The model has a specific agent for collecting biodata and context data, both used in the patient monitoring. Other two agents are in charge of applying interventions and gamification. The modules are exposed in a Web API that provides actions that can be used by both agents and applications.

The modular structure of iAware allows the extension of its functionalities. Agents are independent and communicate through actions managed by the action module and act according to the context in which they are. Applications communicate with the modules through the REST API to show the features and activities specific to each type of user, patient or psychologist. The ontology created in iAware presents domain-related knowledge to the DASD treatment, the focus of this work. In the next subsections, each model component is presented.

2.2.1. Modules

iAware contains five modules, namely Profile, Action, Gamification, Intervention, and Context. The Action, Profile and Context modules are independent (Fig. 1). While the Gamification Module has a dependency relationship from Intervention module, and Intervention module has a dependency relationship from Profile module. This dependence exists because in order to apply gamification, an intervention needs to be performed. And to know what intervention to apply, it is necessary to know the profile of the patient who will receive an intervention.

The Profile Module represents characteristics of the patients' behavior, having information about their activity and sleep schedules, used device applications, if they have any sleep disorder, such as insomnia or drowsiness, and if they have hyperactivity. The Profile Module exposes to other modules functions that allow managing Patient Profiles. This module is independent of the other modules and it can be accessed by any of the other modules.

An Action expresses a necessity to apply gamification or an intervention for a particular patient. Thus Intervention and Gamifier agents will know the moment that they need to act. The Action Module responsibility is managing this gamification and intervention actions used by the model. Thus Action module allows the Monitor and Interventor agents to register the intervention and gamification actions, respectively. This module enables communication between agents and enables them to create notifications of when they need to act on a particular patient. Thus, this module ensures that agents are independent of each other and, at the same time, interact through notifications of actions that they will perform.

Gamification Module is responsible for gamifying the interventions performed by patients. In the iAware, gamification characterizes through a scoring system relating to levels about treatment awareness. These levels are None, Low, Medium and High.

An intervention is a technique applied by patients to reduce the symptom of their disorders, the learning of new techniques

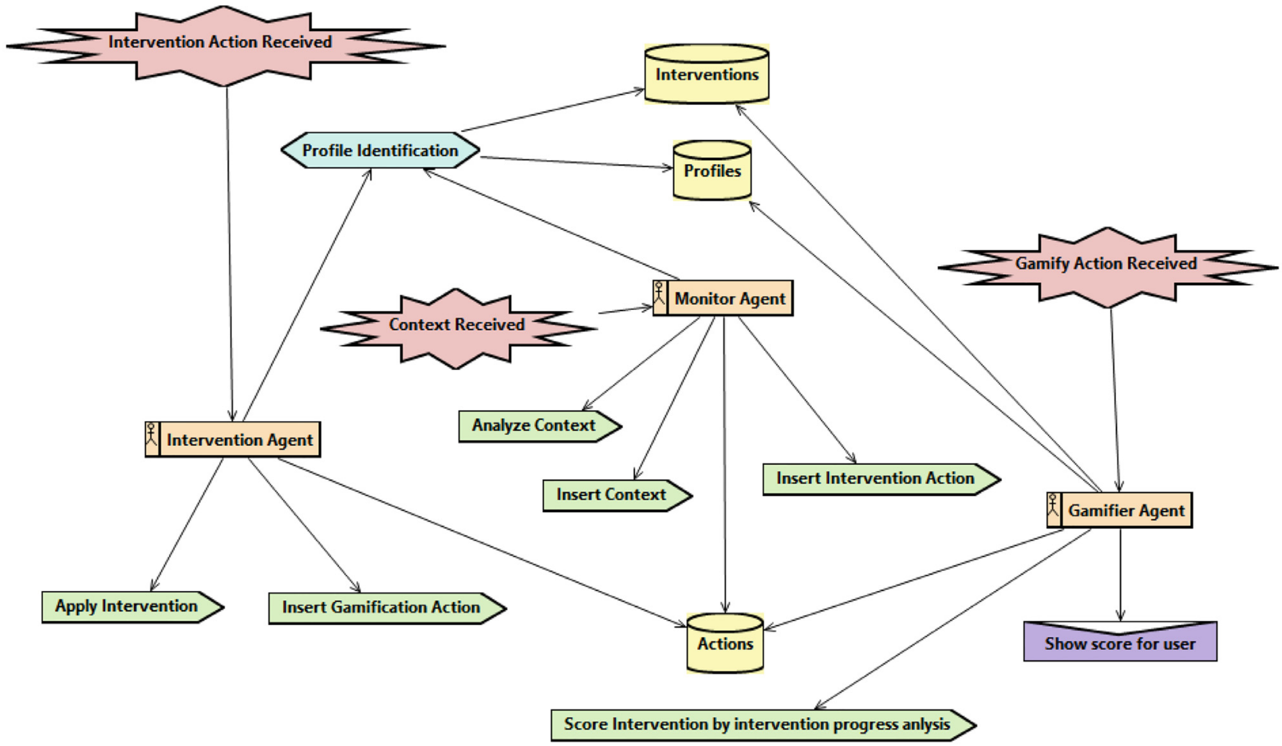


Fig. 2. Overview of iAware agents developed using PDT.

(cognitive and behavioral) by the patients or an information about the nature and the ways of treating their disorders. Thus, the Intervention Module aims to ensure that interventions are made by the Intervention Agent and the Gamification Module. The Intervention Module allows other components of iAware to manage and access the interventions.

The Context Module stores contexts, such as location, heart rate, application time usage, sleep quality and number of steps of a given patient. These temporal data expresses the situation in which the patients currently are. This allows iAware to recognize these situations and their relationship in the patients disorder. Context Module manages the context information and supports the Monitor Agent by providing the stored contexts so it can make inferences through this data. This module does not attempt to capture the context, because the capture is a task of the Monitor Agent.

2.2.2. Agents

iAware has autonomous actions in context data collection to apply interventions and to gamify patients activities. These actions happen continuously and simultaneously adapting themselves according to the user experience, being performed by iAware agents. The agents were designed using the Prometheus Design Tool (PDT). PDT defines a process in detail for the development stage of an agent-oriented system [31]. The PDT is used in the specification, design and implementation.

Fig. 2 gives an overview of the agents, presenting the interactions between the monitor, intervention and gamifier agents.

In order to iAware identifies the best opportunity to make an intervention to the patient, the system needs to be aware of the context in which the patients are, as well as adapting its execution to changes in context. The context is perceived by the agent using position change notification functions, connection networks and biodata. The agent that has this goal is the Monitor Agent.

The Monitor Agent has the following activities:

- Context analyze: It should be able to analyze the most varied contexts, such as location, recognition of behaviors, heartbeats, among others and also be able to interpret when performing an intervention.
- Insert context: It stores the analyzed context, categorizing it according to types, such as a location, behavior, heart rate or sleep quality.
- Insert action of intervention: It registers an intervention action for a given patient, whenever it detects a potential disorder symptom occurring on the patient.

Through the above activities, the Monitor Agent will be able to analyze each received context event. The agent design is generic enough to analyze the context using the most varied algorithms, such as decision tree, machine learning, or another technique. Section 2.3 presents the technique used to analyze the context by this agent in the prototype.

After analyzing the context history, the agent infers if there was a worsening of the patient's mental state and creates an intervention action. This intervention action serves as a notification for the Intervention Agent to act, informing the patients that they need interventions.

In addition to inform which patient needs to insert an intervention action, the Monitor Agent also stores the context where the symptom occurred, this creates a context history and the Monitor agent itself can benefit from this information for the next context analysis. The Monitor Agent does not depend on any other agent, being autonomous in its actions based only on the context, where it makes its inferences.

One of the goals of iAware is to apply interventions for patients suffering from DASD, this action is performed by the Intervention Agent. Upon receiving the intervention notification the agent identifies the patient's profile and selects the best type of intervention for that particular patient.

The activities of the Intervention Agent are the following:

- Apply intervention: Through the analysis of the patient's profile the agent selects the most appropriate intervention to apply at a given moment.
- Measure efficacy: This activity serves to measure the user acceptance to a particular intervention. The measure of acceptance analyzes the attitude taken by the user through the intervention. Thus, the measure of effectiveness is according to the visualization and conclusion of the intervention.
- Insert gamification action: It registers a gamification action for a given patient, whenever it detects the conclusion of an intervention performed by a patient.

The Intervention Agent ensures that iAware adapts to the patients as it identifies their habits. The profiles assigned to patients have characteristics of their behavior, allowing the agent to recommend an intervention. The context stored in the database has information about the date and time, context value and type, and patient identification. Thus, context history is generated allowing a user analysis based on earlier attitudes, identifying patterns and making inferences that will allow a more adequate intervention offer to the patient.

In addition, the Intervention Agent measures the effectiveness of this intervention before applying it. This measurement varies according to the type of DASD, thus allowing a specific evaluation for each type, and therefore having a more assertive measurement. When a patient complete the intervention the Intervention Agent creates a gamification action. This gamification action will serve as a notification for the Gamifier Agent to act, informing patient identification and the performed intervention.

Gamification techniques are used to increase engagement in applications. The iAware uses gamification for this purpose, and the Gamifier Agent responsibility is to guarantee the gamification applicability when an intervention ends.

The Gamifier Agent has the following activities:

- Apply gamification: It scores the intervention performed by the user, taking into consideration the execution time and completeness of the intervention. Thus allowing the patient progress reflect also in the system through the gamification usage.
- Provide patient motivation to perform interventions: This assignment serves the patient to stay active in their disorder treatment. Thus, patients who are not interacting with the system or who are decreasing this interaction could be encouraged.
- Show gamification to the patient: It introduces gamification properties such as score, progress and medals to the patient, encouraging the patient to continue using the tool and performing the interventions.

Gamification in the iAware provides a patients engagement mechanism in the treatment, stimulating patients to do the interventions. The Gamifier Agent scores the interventions performed by patients, allowing the patients' level and medals to be obtained while using iAware. In addition, this agent enables patients to have a current overview of their score and level while using the system. These techniques will encourage patients keeping with their treatment. The Gamifier Agent does not guarantee patients will remain in their treatments, but it is an essential part of iAware to provide engagement with it.

2.2.3. Patient application

This application provides suggestions of intervention to patients through notifications and that they actually do this intervention (Fig. 1). In addition, the Patient Application presents gamification features such as score, level of treatment awareness and rewards from their. The Patient Application should always be nearby patients to offer interventions at the most proper time.

The Patient Application have access to some of the patients' personal data, such as email, name, age, disorder and list of their psychologist. This data is encrypted on the server-side. Internally, iAware protects the patient information by using a unique random code.

Thus, the Patient Application will always be able to monitor, notify, apply the intervention and engage patients through gamification. Therefore Patient Application can be composed by one or more devices that can work together to guarantee these four characteristics described above.

2.2.4. Administrative application

In order for iAware to get basic information on a patient's disorder symptoms and for their psychologist to see the patient's performance for each intervention, there is an Administrative Application. The purpose of this application is to report on the progress of patients based on the number of interventions performed. Also, it shows which interventions were most effective for patients, measured through the score obtained by the gamification. It also allows the psychologist to continuously update the patient's profile, being able to change the characteristics previously configured.

Professional follow-up and constant updating the profile ensure that iAware has a better understanding of patients' behavior. This understanding enhances the application of more appropriate interventions. Thus, the system has two forms of feedback from patient behavior, one based on the user context history and another on the patients' profiles which are updated by their psychologists.

Unlike the Patient Application, the Administration Application is used only when the patients' psychologist finds it convenient to access patients' data or wishes to update their profile.

2.2.5. iAware ontology

One of the advantages of using ontology is to structure knowledge that will later be shared between agents and other systems. Fig. 3 shows the proposed ontology. It represents knowledge about the ubiquitous care domain of DASD expressing a global vocabulary between the iAware components.

The Person class can be a Professional or a Patient. The Professional class can be of type Psychologist or Psychiatrist and it has a relationship with the Patient class since it represents the professional who treats one or more patients.

The "has" relation from patient shows the specific mental disorder the patient is carrying. Mental Disorder can be of type Anxiety, Depression or Stress. The "are" relation from patient describes the patients' level of awareness about their mental disorder at any given time. Awareness level can be None, Low, Medium or High. The "is in" relation from patient displays the context in which the patient is in a given moment. A Context is a generic representation of the information that "express" the situation of an entity [32]. A Context is "composed by" a value that represents it, in this ontology the values are of type Time, Location, Heart Beat, Application Usage, Quantity of Steps or Time of Sleep.

An Action represents an event execution in the system and is of type Gamification or Intervention. The relationship "suggests to" denotes that an action is assigned to a patient.

2.3. Evaluation aspects

The implementation of a prototype allowed the evaluation of iAware. In this section, the implementation aspects of the modules, agents and patient application, as well as the proposal of experimentation and validation of the prototype are presented.

2.3.1. Prototype implementation

The prototype was implemented through an application to run on Android operating systems in version 5 or higher, enabling it to

Please cite this article as: L.P.S. Dias, J.L.V. Barbosa and L.P. Feijó et al., Development and testing of iAware model for ubiquitous care of patients with symptoms of stress, anxiety and depression, Computer Methods and Programs in Biomedicine, https://doi.org/10.1016/j.cmpb.2019.105113

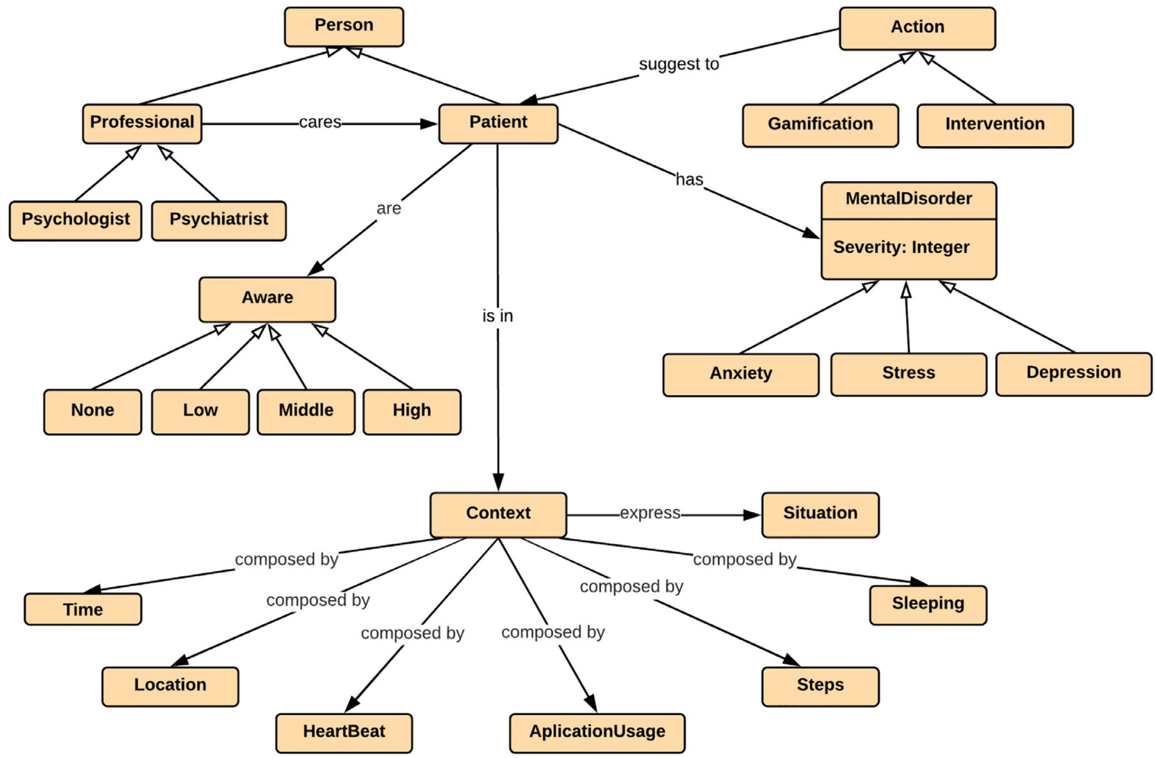


Fig. 3. iAware ontology.

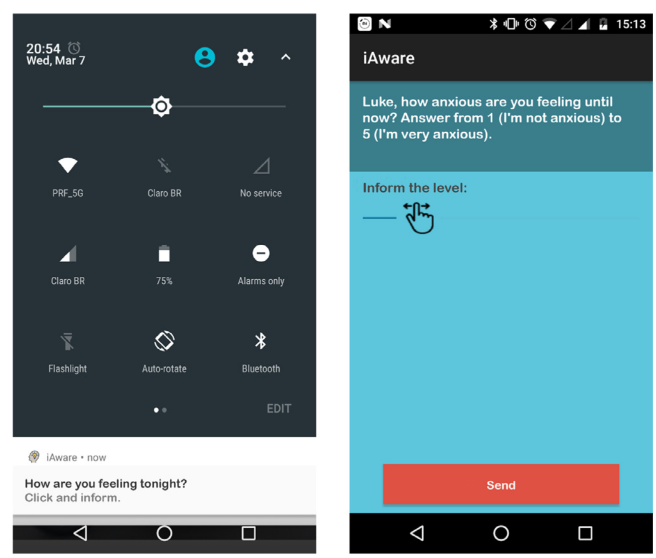
work on a range of devices. All modules and agents were implemented, allowing to evaluate the main functionalities of the model and perform interventions with patients during their daily activities. The prototype worked without the need of an Internet connection, and when established a connection the application automatically synchronizes the data through an ASP.NET Web API REST in JSON format.

Patient Application implements the three agents and the user interface in which the patient performs the interventions. Each agent is a BroadcastReceiver to work with the Android AlarmManager library. Agents communicate through action registers, allowing another agent to know when to act for a particular patient. The user application is available on the Google Play,[1] making it easy to install and upgrade on Android smartphones. The application collects biodata from the patient through the bluetooth low energy communication with a smartband Mi Band 2.

The iAware collects the number of steps and the patients' heart rate as a way to identify anxiety moments. Data analysis occurs by observing a 5-minutes window, where the steps per minute can not exceed 96 steps, since a greater number of steps is already considered physical activity [33], and the average heart rate in this window can not be greater than 100 bpm [34]. In addition to this form of anxiety moments identification, the application asks the patient anxiety level in the morning (9am–12pm), afternoon (3pm–6pm) and night (8pm–11pm).

When iAware identifies anxiety moments a notification is generated on the patients' smartphone, asking what is the perceived anxiety level by their (Fig. 4), on a Likert scale of 1 (I'm not anxious) to 5 (I'm very anxious) points.

If patients indicated the perceived anxiety level equal to or greater than 3, iAware suggests an intervention, which may be done or not. When patients touch the notification (Fig. 5(a)), a screen is seen where they can choose one of the CBT techniques.



(a) (b)

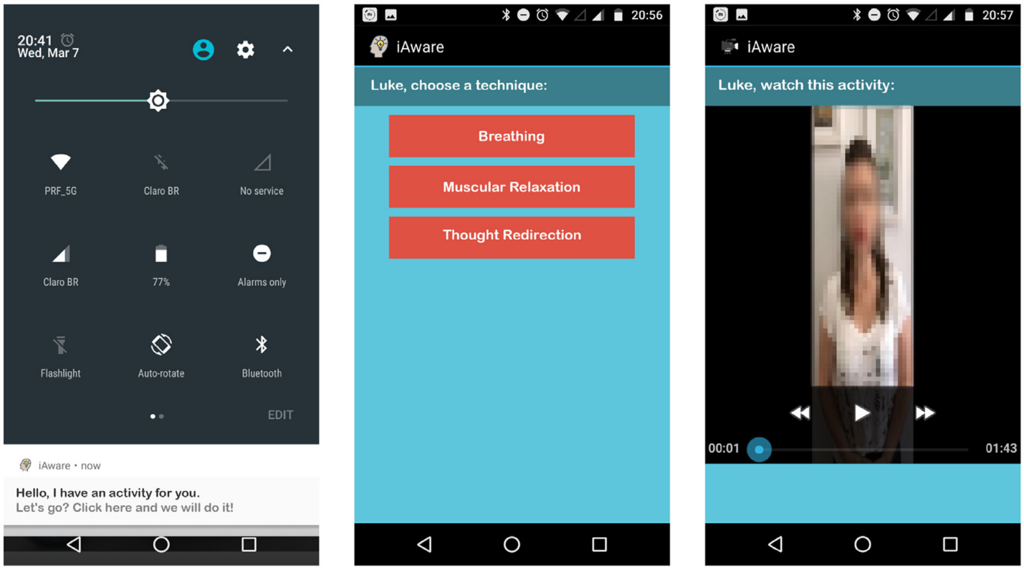
Fig. 4. Screens of notification (a) and anxiety level indication (b).

The iAware uses three intervention techniques, being techniques of breathing, muscular relaxation and thought redirection (Fig. 5(b)). After the patient had chosen a technique, an instructive video is presented for performing the technique (Fig. 5(c)).

After the patient had watched the video and performed the technique, the patient is redirected to iAware home screen, where the patient level, score, and medals acquired when performing interventions are presented (Fig. 6(a)).

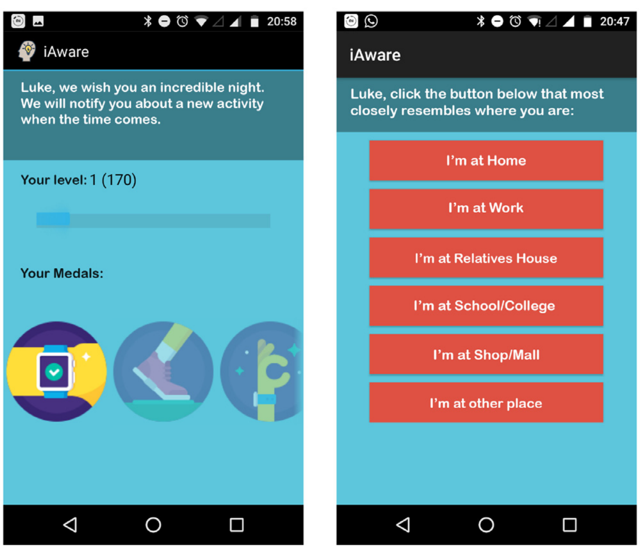
[1] iAware Google Play address https://play.google.com/store/apps/details?id=com.iaware&hl=pt_BR.

Please cite this article as: L.P.S. Dias, J.L.V. Barbosa and L.P. Feijó et al., Development and testing of iAware model for ubiquitous care of patients with symptoms of stress, anxiety and depression, Computer Methods and Programs in Biomedicine, https://doi.org/10.1016/j.cmpb.2019.105113



(a) (b) (c)

Fig. 5. Screens of intervention notification (a), choice of technique (b) and video of a technique (c).



(a) (b)

Fig. 6. Home screen (a) of the iAware Gamified and Wi-Fi identification screen (b).

When the prototype identifies a new Wi-Fi connection, it allows the patients to identify they location (Fig. 6(b)), hence trying to relate the patients location and the relationship of perceived anxiety level.

The model has methods that anonymize patients and each patient receives a randomly generated code. All data collected from smartphone and smartband Mi Band 2 are linked with respective patients' random codes.

The Patient Application was developed as native Android applications using XAMARIN and C#. However, the Administration Application was not implemented in this work because it was not considered a vital item to model feasibility evaluation.

The prototype stores data in a SQL Server relational database. This platform is robust, reliable and easy to integrate with the C# programming language. Patient data is protected by encryption and data traffic is over HTTPS, not allowing patient identification. In addition, context data was associated with a globally unique identifier (GUID) for patients at the time of their iAware registration.

The ontology has the purpose of establishing a common vocabulary between the agents and other components of the model, besides allow other systems extended it. The format of this vocabulary and instances are expressed in JSON.

Table 2
Items related to evaluation of perceived utility in iAware.

Question	Description
1	Notification of activities is useful in the anxiety treatment routine.
2	Anxiety alerts are useful in the anxiety treatment routine.
3	The ability to use the application without relying on the Internet is useful.
4	The resources of scoring, progress and medals are useful for anxiety treatment routine.

2.3.2. Evaluation

The iAware was evaluated through a randomized experiment in the form of an A/B Test [35] and upon execution, the users would answer an assessment questionnaire based on the Technology Acceptance Model (TAM), following the guidelines defined by Davis [36]. This model measures the satisfaction through perceived usefulness and perceived ease of use. The TAM model has been considered a standard to evaluate the acceptance of new technologies [37]. During all prototype experimentation time, patients were accompanied by their psychologists.

TAM model uses two categories to measure the user satisfaction: perceived utility and perceived ease of use [36]. Perceived utility is used to determine if the proposed technology can help the user to perform an activity more adequately, while ease of use evaluates whether the technology can be used with the least effort. In this way, the evaluation questionnaire had two categories, usefulness and ease of use. The questionnaire consists of five-level Likert items that are 'strongly disagree', 'disagree', 'neutral', 'agree' and 'strongly agree'. The evaluation items are described in Tables 2

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Table 3
Items related to evaluation of perceived ease of use in iAware.

Question	Description
1	The smartband is easy to set up in iAware.
2	The alerts of new Wi-Fi connection are easy to understand.
3	The alerts of new activity are easy to understand.
4	The alerts of anxiety are easy to understand.
5	The videos of techniques are easy to understand.
6	The anxiety survey is easy to understand.

and 3, where the item 4 from Table 2 was only asked to patients who used the iAware.

In order to evaluate the results, the percentage of selection of each option (‘strongly disagree’, ‘disagree’, ‘neutral’, ‘agree’ or ‘strongly agree’) per question was computed. In this sense, the percentages obtained for each option according to the category of the question (utility or ease of use) were averaged. The mean of the percentages for each option is equivalent to the average satisfaction index evaluated by the volunteer patients for each category. The primary outcome was obtained through the average satisfaction indexes for the categories of utility and corresponding ease of use of each group.

The first stage of the evaluation was the selection of participants for the experiment. The research team contacted the psychologists in their network of contacts individually, by e-mail and telephone, in order to identify patients with anxiety symptoms. If the psychologist was treating patients with the desired profile, it was checked with the psychologist about the possibility of contacting these individuals to identify if they would want to participate in the study. At the end of this stage, 6 people with anxiety symptoms participated in the study. From the beginning of the study, researchers from the Post-graduate Program in Psychology of UNISINOS, a Private University of Southern Brazil, were contacted to take part of the research team of this work, assisting in the study and collaborating in the professionals’ identification who could participate in the experiment.

The second stage of the experiment consisted of presenting the iAware features to the volunteer patients. These features include the configuration of the smartband Mi Band 2 with iAware, perceived anxiety notification and anxiety grade indication screen, intervention notification, selection and application technique, and Wi-Fi indication. All patients in this study signed the free and clearly consent term to participate in the experiment. When necessary, all the participants were followed up by their psychologists for the treatment concomitant with the research.

Patients were separated into two equal groups, where one of the groups used the the gamified version of iAware. Both groups used the iAware installed on their smartphones for a maximum of two weeks. The iAware notified the user during their daily activities when intervention was required. During the experiment, the patients could contact their psychologists at any time by telephone, in addition to the weekly sessions already established with the psychologists, for explain any doubts or discontinuance of their participation in the experiment. After the end of the experiment, the patients returned the smartband Mi Band 2 to their psychologist.

After two weeks of using iAware, the volunteers were asked to respond to a TAM questionnaire. The assessment measured how gamification increased user engagement in using iAware by evaluating the interaction of groups in the prototype. Interaction was measured by comparing the number of notifications for activities, the number of activities performed and the number of activities scored by the patient.

2.4. Participants

Participants were selected from a convenience sample [38] of patients in psychotherapy care by cognitive-behavioral psychologists in private practice. The distribution of participant groups occurred non-randomly. It is noteworthy that participants consented to be allocated into one of two groups, one using iAware with gamification and one using iAware without gamification.

Diagnostic assessments were performed using SCID-5 CV [39] in an initial clinical screening interview by licensed psychologists with at least two years of clinical experience and psychological care. Throughout the experiment, patients were followed weekly by psychologists, who evaluated the prognostics by both clinical observation and the use of iAware. Psychologists have devoted special attention to follow possible effects regarding depressive symptoms. If negative prognostics were detected, the treatment would be continued weekly, but without the iAware usage. After iAware usage, a clinical interview was performed as a form of model evaluation since it was a pilot study with patients under treatment.

Thus, the therapists indicated engagement/motivation, gratification for the progress of treatment, self-management by patients themselves of their clinical difficulties, and finally, suggestions for iAware improvement. The results show that iAware can positively complement therapeutic work and preliminary results indicate a good acceptance of iAware by therapists and patients.

3. Results

Six patients evaluated iAware. The results were organized in the following subsections: gamification evaluation, where anxiety happens, when anxiety happened, how anxiety happened, CBT techniques evaluation and TAM evaluation. The patients that used iAware gamified were identified as P1, P2 and P3, while those who used the non-gamified version were identified as P4, P5 and P6.

3.1. Gamification evaluation

At the end of the iAware usage, the patient’s interaction was collected. This interaction had three stages, being the notification, achievement and punctuation of the activity. Fig. 7 presents the number of notifications for activities, amount of activities and scored activities by patient.

Patients who used the iAware gamified had homogeneous interactions, performing the three stages, while the patients who did not use the gamification had not performed the three steps in all interactions. This result shows indications of the lack of patients commitment, who did not use the gamification, in all interaction stages accomplishment. However, the users who used gamification during the two weeks of the experiment had only one moment of anxiety, whereas the group that used the prototype without the gamification had more moments of anxiety.

3.2. Where anxiety happens

This analysis aimed to identify in the test group in which places occurred anxiety moments. Patients could identify the locations they were by six options being: home, work, school/college, relatives house, store/mall, and others. When not identified, the category “other” was automatically considered.

Table 4 presents the locations where anxiety occurred. For patients P1 and P5 the house was the only place where anxiety occurred during the two weeks of iAware usage. Patients P2 and P3 the anxiety occurred only in their relatives house. Patient P6 reported anxiety at home and at “other places”. Patient P4 was the one who reported anxiety in a greater diversity of places, being identified the home, school/college and “others”.

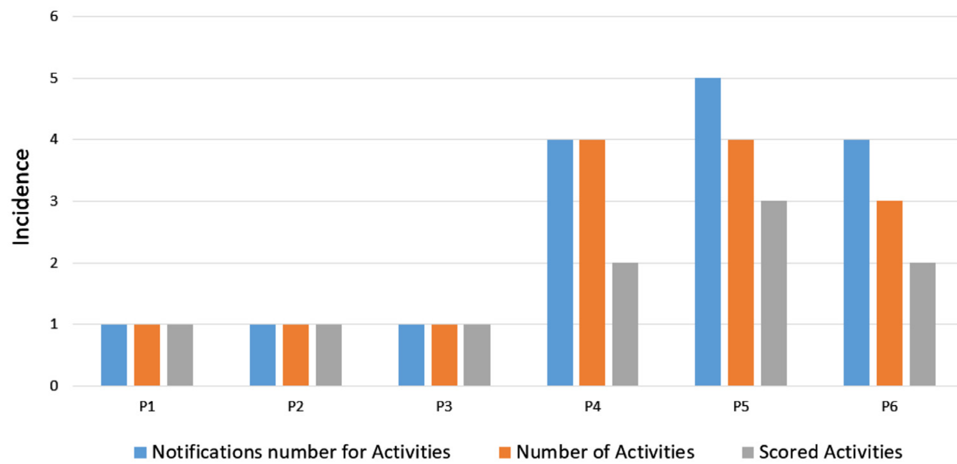

Fig. 7. Users score of techniques.

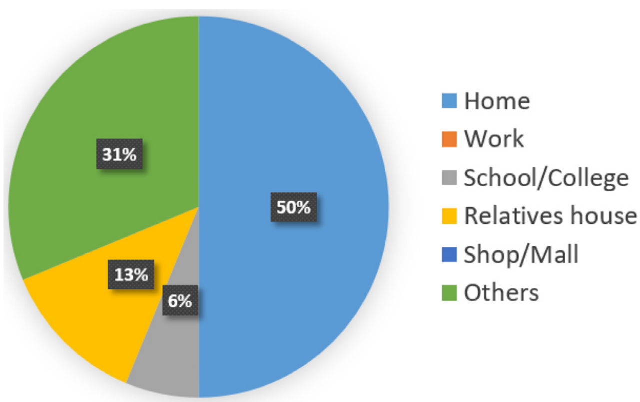

Fig. 8. Locations with higher occurrence of anxiety.

Table 4
Number of occurrence of anxiety per patient and place.

Patient	Home	Work	School/College	Relatives house	Shop/Mall	Others
P1	1	0	0	0	0	0
P2	0	0	0	1	0	0
P3	0	0	0	1	0	0
P4	1	0	1	0	0	2
P5	5	0	0	0	0	0
P6	1	0	0	0	0	3

Fig. 8 presents the locations data compiled, the two places with the highest occurrence of anxiety among the analyzed patients, the place identified as home, followed by others. These data indicate that for the patients analyzed, the house where they live, being an anxiety point, could count with resources for an intelligent home, thus improving the monitoring and treatment of these patients at this environment. One of the possible approaches in a smart home would be to adjust the lights and play a relaxing ambient sound that will lower the anxiety level [40,41].

3.3. When anxiety happened

In order to evaluate the parts of a day where anxiety happened, the anxiety perception was evaluated with the minimum level of 3, from a scale of 1 (not anxious) to 5 (very anxious). The Table 5 presents the parts of a day where patients indicated the anxiety occurrence, where for this patients group the greater anxiety occurrence were afternoon and night, having no anxiety occurrences in the morning.

Table 5
Parts of a day with higher anxiety incidence.

Patient	Morning	Afternoon	Night
P1	0	0	1
P2	0	1	0
P3	0	1	0
P4	0	2	2
P5	0	3	2
P6	0	1	3

3.4. How anxiety happened

To understand how anxiety happened, the patients' behavior during the moments of anxiety, such as the number of steps, the average heart rate per minute (BPM) and greatest heart rate were captured and analyzed.

Table 6 shows the biodata observation interval, the trigger and the level of anxiety perceived by the patient, where the average BPM ranged from 66.61 to 93.01. The maximum BPM ranged from 92 to 165, with the highest BPM values of 165 (P6) and 129 (P2), BPM averaging 82.07 and 80.94 BPM respectively. Patients P4 and P3 reported the greatest perceived anxiety level, with maximum BPM of 108 and average of 83.06 BPM and maximum BPM of 112 and average of 66.61 BPM, respectively.

Lines 3 and 11 present, by Bio Observation triggers, that both P2 and P4 patients had heartbeat changes at night, however, their reported low anxiety levels. In a talk between the project team and psychologists participating in this research about this occurrence, psychologists were inclined to believe that this trigger possibly was in fact due to anxiety, but not interpreted by patients. Psychologists believe that if the question mentions sleeping difficulties instead of perceived anxiety the result could have been more assertive, since insomnia is an anxiety characteristic, even if it is not so interpreted by the patient.

Lines 4 and 5 show two triggers by Bio Observation of patient P2, where this patient has performed exercises and then rested. Analyzing the 5 min before the Bio Observation trigger occurred the physical activity was identified, due patient P2 was increasing the number of steps in an average of 100 per minute, which is already considered physical activity.

This statement becomes more clear when compared to the amount of steps taken between patients. In a 2 h observation window, the patient P2 had a greater amount of steps given than the

Table 6
Behavior when anxious.

	Patient	Steps	BPM avg	BPM max	Interval	Trigger	Anxiety
1	P1	not captured	not captured	not captured	19h - 23h59	Anxiety Test	Level 3
2	P2	not captured	not captured	not captured	14h - 18h59	Anxiety Test	Level 3
3	P2	10	80.94	129	02h - 03h59	Bio Observation	Level 2
4	P2	2577	119.61	164	13h - 14h59	Bio Observation	Level 1
5	P2	2390	91.44	137	16h - 17h59	Bio Observation	Level 1
6	P3	1708	66.61	112	16h - 17h59	Anxiety Test	Level 5
7	P4	1550	93.01	120	14h - 18h59	Anxiety Test	Level 3
8	P4	530	83.06	108	19h - 23h59	Anxiety Test	Level 5
9	P4	2136	88.27	115	14h - 18h59	Anxiety Test	Level 3
10	P4	882	87.15	129	19h - 23h59	Anxiety Test	Level 3
11	P4	13	92.43	110	02h - 03h59	Bio Observation	Level 2
12	P5	124	78.2	92	19h - 23h59	Anxiety Test	Level 3
13	P5	not captured	not captured	not captured	14h - 18h59	Anxiety Test	Level 3
14	P5	765	75.45	126	14h - 18h59	Anxiety Test	Level 4
15	P5	777	72.24	106	14h - 18h59	Anxiety Test	Level 3
16	P5	not captured	not captured	not captured	19h - 23h59	Anxiety Test	Level 3
17	P6	1862	81.18	137	19h - 23h59	Anxiety Test	Level 3
18	P6	851	84	131	14h - 17h59	Anxiety Test	Level 5
19	P6	239	73.75	136	19h - 23h59	Anxiety Test	Level 4
20	P6	3370	82.07	165	19h - 23h59	Anxiety Test	Level 3

Table 7
Techniques more used.

Patient	Breathing	Muscular relaxation	Thought redirection
P1	0	1	0
P2	1	0	0
P3	1	0	0
P4	2	1	1
P5	1	1	2
P6	2	1	0

patient P4, which obtained 2136 steps in a 5 h observation window (Table 6). This false positive occurred because the observation window of 5 min was not enough for the heart rate normalize, confirming the minimum anxiety level informed by the patient, indicating the anxiety absence.

3.5. CBT techniques evaluation

The interventions offered to the patients came from Cognitive-Behavioral Therapy (CBT) and were the same for both groups. Table 7 presents that the techniques most used by patients, were the breathing technique which obtained 7 occurrences, followed by muscular relaxation with 4 occurrences and thought redirection with 3 occurrences. Another characteristic is that patients P4 and P5, who had 4 occurrences of anxiety, used all three techniques available in iAware. Having P4 used more the breathing technique, while P5 used more the thought redirection technique.

Another analysis evaluated the techniques through the average score given by the patients. When finalizing the video technique, the patient could rate the technique with a score of 1–5 points. This evaluation considered only the rated tasks.

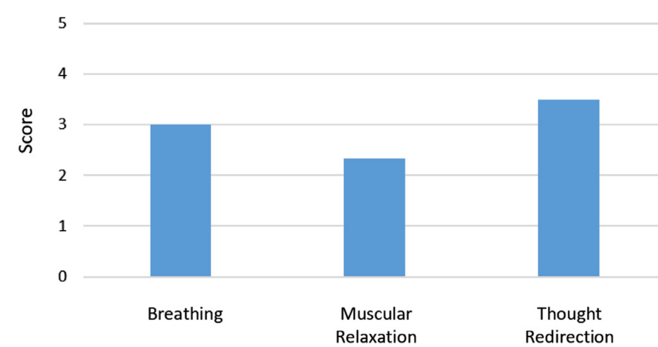

Fig. 9. Techniques score by users.

Fig. 9 presents that the thought redirection technique was the one that received the highest score average, 3.5 points. In second place was the breathing technique that obtained 3 points and finally the muscular relaxation technique, with 2.33 points.

3.6. TAM evaluation

Evaluation of usefulness and usability perceived by patients occurred at the end of the experiment. Thus, users answered an electronic TAM questionnaire using the Google© Forms tool.

The TAM results for the utility-related issues (Table 2), were that 33% of patients agree that activity reporting is useful in the anxiety treatment routine, whereas 67% are neutral (Fig. 10(a)).

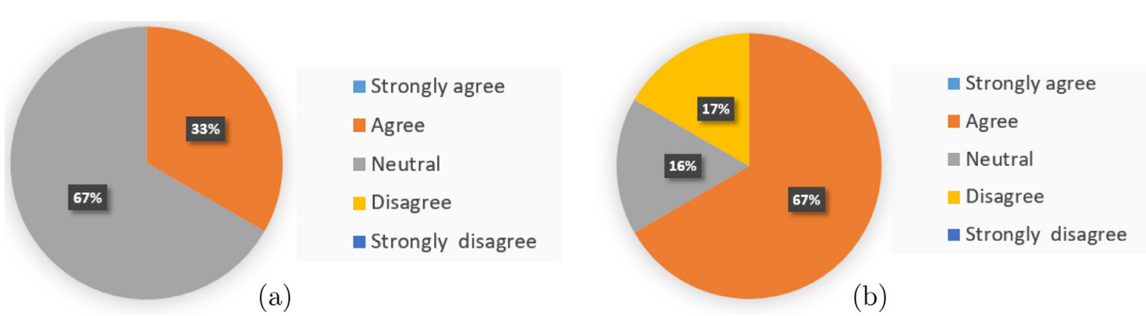

Fig. 10. Utility perceived by the patients in the notification of activities (a) and anxiety alert (b).

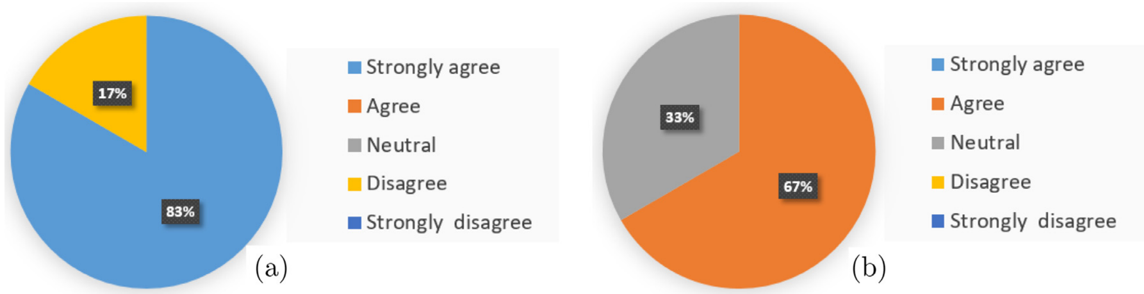

Fig. 11. Utility perceived by patients in the application does not depend on Internet (a) and on gamification resources (b).

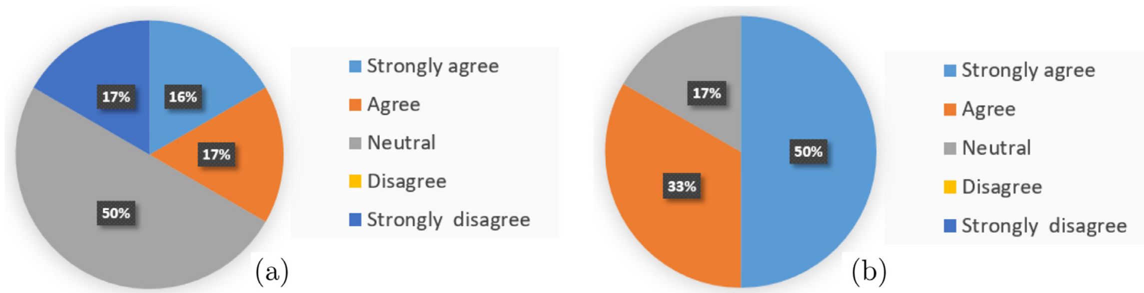

Fig. 12. Usability perceived by patients when configuring the smartband (a) and notifications of a new Wi-Fi connection (b).

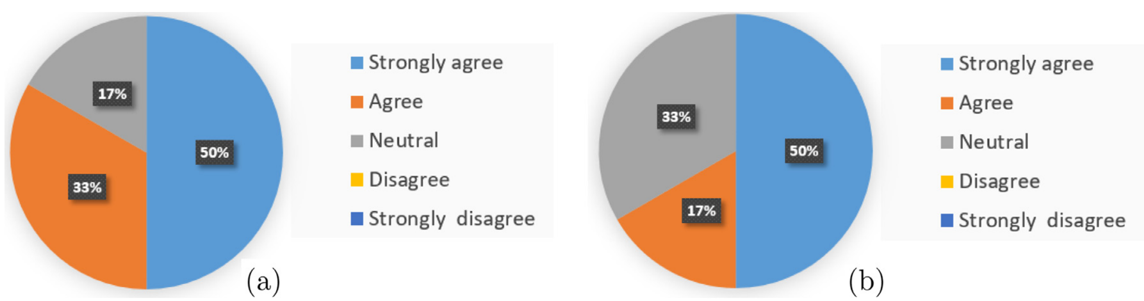

Fig. 13. Usability perceived by patients in activity reports (a) and in anxiety reports (b).

Fig. 10(b) shows that 67% of patients agree that anxiety alerts are useful in the anxiety treatment routine, while 16% are neutral and 17% disagree. Those who disagreed, the probable cause could be the anxiety alert that triggered every day in the morning, afternoon and evening, asking the patients" level of anxiety even when he was not anxious.

The application usage without relying on the Internet was considered useful by 83% of patients and 17% disagreed (Fig. 11(a)). The possible reason of disagreement was due to data plan usage, allowing them to always be connected on the Internet. And for patients who have used the gamified iAware, 67% agree that score, progress, and medal features are useful in the anxiety treatment routine, while 33% of patients are neutral (Fig. 11(b)).

About the results related to usability, 16% of patients strongly agreed that the smartband is easy to set up, 17% agreed, 50% are neutral, and 17% strongly disagreed (Fig. 12(a)). Those who strongly disagreed, the reason have been due to the delay in the Bluetooth Low Energy (BLE) connection between the smartband and the smartphone, needing to reconnect the smartband a few times. Fig. 12(b) shows that 50% of users strongly agreed that new Wi-Fi connection alerts are easy to understand, 33% of patients agreed and 17% are neutral.

The alerts of new activities are easy to understand, 50% of patients strongly agreed, 33% agreed and to 17% were neutral (Fig. 13(a)). Fig. 13(b) shows that 50% of patients strongly agreed, 17% agreed and 33% were neutral about anxiety alerts being easily understood.

Fig. 14(a) shows that 83% of patients strongly agreed that video techniques were easy to understand and 17% were neutral. And finally 33% of patients strongly agreed, 50% agreed and 17% were neutral about whether the anxiety questionnaire was easy to understand (Fig. 14(b)).

The responses of each category, utility and usability were generally positive. The average patients' results for questions related to the iAware utility are presented in Fig. 15(a). Showing that 33% of the patients, who used iAware, strongly agreed that the application was useful to their treatment routine, 50% agreed and 17% were neutral. About the iAware usability, 83% of patients strongly agreed that iAware was easy to use and 17% disagreed (Fig. 15(b)). iAware obtained a good evaluation of the usefulness and usability by the patients.

4. Discussion

This text presented a model for ubiquitous care of DASD patients using gamification and biodata, called iAware. iAware design is based on the common characteristics and gaps identified in the related works [8,16,18,21–23]. The results point out that biodata is a supplementary alternative for DASD monitoring and show that the use of iAware for the support of anxiety treatment is possible and useful to the patients.

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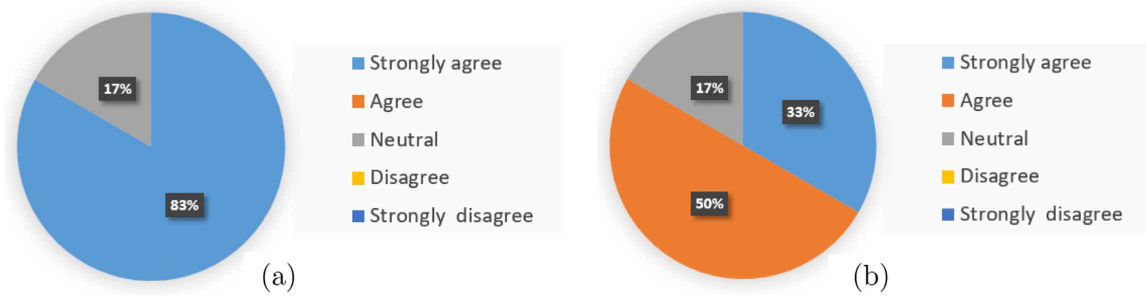

Fig. 14. Usability perceived by the patients in the technique videos (a) and in the anxiety questionnaire (b).

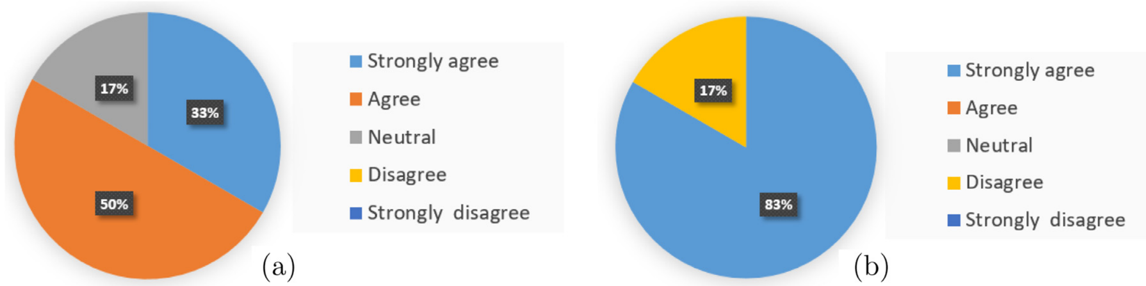

Fig. 15. General utility (a) and usability (b) perceived by patients.

Gamification analysis was performed through user interaction during intervention activities. The interaction had three stages, being the notification, perform and score of the activity. Only patients who used the gamified iAware completed all steps. Patients who used iAware without gamification did not perform or score the activity at some time. This evaluation showed evidence that gamification improved the engagement of patients to complete the three steps of the interaction in iAware. The places evaluation where anxiety occurs indicates that the patients had the highest incidence of anxiety in their home, suggesting that this place could have resources of a smart environment for improving monitoring and treatment of the anxiety of the analyzed patients. The morning and afternoon had both eight anxiety occurrences. This outcome makes it possible to define strategies to decrease the level of anxiety of these patients in the parts of a day identified as potential anxiety moments.

Through the analysis of patients' behavior, possible anxiety' moments were identified in two patients at dawn, however, the patients identified this moment as a low-level of anxiety. Through a talk with psychologists about this behavior, they incline to believe that this behavior really was anxiety moment and believe that if the iAware question mentioned difficulties in sleeping instead of perceived anxiety, the patients' response could have been more assertive. Thus, this study indicates the feasibility of biodata usage for monitoring of patients with anxiety disorder.

TAM evaluation identifies improvement points in iAware, especially about anxiety alerts utility, where 17% of patients did not find it useful. 17% of patients related difficulties in to configure the smartband in the prototype, showing that configuration usability between smartband and iAware needs improvement.

The diagnosis was not performed by a psychiatrist, but only by psychologists who did not evaluate the diagnostic differences in anxiety disorders. Therefore, the evaluation had groups of patients with distinct anxiety degrees and it could affect the evaluation between groups who used iAware with and without gamification.

In future works biodata observation window will be increased to mitigate false positives since the evaluation identified moments of anxiety resulted from an increase in heart rate when resting after physical activity.

Finally, the Monitor Agent will be improved to analyze the anxiety moments taking into account the context history with the places and parts of a day with greater anxiety occurrence, feeding the agent with these information and allowing to use techniques of artificial intelligence, that explore automatic learning models.

4.1. Clinical application of the tool

The results suggest that iAware may improve the benefits of face-to-face psychotherapeutic treatment and increase patient involvement and motivation for self-management. International studies show promising results for the joint application of psychotherapy and information technologies [8,22,42–44]. The use of iAware concurrently with the therapeutic process can enable faster and more attractive treatment for the patient.

However, in the Brazilian scenario, these practices are still incipient, considering the recent regulation introduced by the Federal Council of Psychology of Brazil related to psychological services provided through information and communication technologies [45].

Regarding to interventions in the cognitive-behavioral approach, iAware can be improved through specific tools related to the Daily/Dysfunctional Thinking Record to aid in cognitive restructuring.

A limitation of this study was the reduced number of pairs of psychotherapists and patients who used the iAware. A greater number of pairs is required to confirm and consolidate the initial results related with the clinical application of the iAware. Besides, additional gamified intervention strategies may be applied to other psychotherapeutic practices. The accelerated integration between applied computing and psychology has stimulated the adoption of solutions in this area of research.

5. Ethics statement

The research work described in this article was approved by the ethics committee of Unisinos with the code (CAAE 90200318.9.0000.5344) available at Plataforma Brasil (http://plataformabrasil.saude.gov.br). All participants signed the Free and

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Informed Consent Term (TCLE) containing the specification about the research goals, risks and benefits. A relevant ethical aspect is that there were no losses in the quality of treatments offered by psychologists.

Declaration of Competing Interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Acknowledgments

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. The authors wish to acknowledge too the support of CNPq/Brazil (National Council for Scientific and Technological Development - http://www.cnpq.br). We are also grateful to Unisinos (http://www.unisinos.br) for embracing this research.

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