

Usability of the PAL Objectives Dashboard for Children’s Diabetes Self-Management Education

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ABSTRACT

Children will only benefit from educational technologies and e-coaches when they understand the long-term consequences and are (intrinsically) motivated to use these support systems. This paper presents an Objective Dashboard that integrates educational achievements, goals and tasks with gamification features (such as challenges, scores and rewards) to advance the interests and engagements of children with type 1 diabetes when using the Personal Assistant for a healthy Lifestyle (PAL) system. By linking in-app activities (e.g., play a quiz or keep a diary) to relevant educational achievements, and to skills and knowledge required in daily life, we aim to increase intrinsic motivation and thereby usage. We designed a dashboard displaying personalised achievements, learning goals and tasks in the domain of diabetes self-management education. We used common user interface design patterns such as layering, colouring, and iconic presentation to organise complex information and reinforce the relations between concepts. Subsequently, we conducted a usability evaluation with twelve children, on the basis of which we refined our design. We found that, colouring and layering were to some extent effective, however, iconic representations were insufficient. Therefore, we recommend to provide short, descriptive labels at any time.

CCS CONCEPTS

•Human-centered computing → Usability testing; Empirical studies in HCI; Visualization design and evaluation methods; •Applied computing → E-learning;

KEYWORDS

healthcare, education, learning goal, gamification, personalization

1 INTRODUCTION

eLearning systems in general, and more specifically Intelligent Tutor Systems (ITS), offer great possibilities; current state-of-the-art

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ICSLT 2019, Vienna, Austria

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DOI: xx.xx/xxx.x

media technologies facilitate learning anywhere anytime, independent of a trainer and institute. However, the success of this *self-regulated* learning is fully dependent on adherence and thus requires high (intrinsic) motivation [37]. Further, these technological advancements support tailoring of learning process and material (e.g., [11, 13, 21, 36]) leveraging on personalization, which is believed to increase relevance and thereby motivation. However, provision of long-term interesting interactions remains a challenge. For example, Leite et al. [20] concluded that, when using robots in education and health care, novelty wears off quickly and interaction diminishes. But also eLearning courses in higher education show high drop-out rates [30]. The implementation of game features in eLearning applications (i.e., *gamification*) is a popular means to increase and maintain interest [6]. However, gamification benefits risk depletion once rewards lose their value. A more traditional technique improving task performance is goal-setting [23]. In classroom teaching, goals influence motivation [1] and learning outcomes [3]. Goal-setting also has been applied to ITS (e.g., [5, 19]).

One such context, where self-regulated learning is crucial, is diabetes self-management education. For day-to-day diabetes management children need to acquire, from early on, specific knowledge, skills and attitudes. This progress towards self-management is not straightforward and the path should be personalised [33]. Drawing from both gamification and educational sciences, educational objectives have been added to the *PAL system*¹: a mHealth application providing personalised, diabetes self-management education.

The *PAL system* includes web-based dashboards for caretakers, an app with a medical diary, quiz and several mini games for children, and a (virtual) robot ‘pal’. To enhance motivation for and usage of the app, and ultimately learning gain, educational achievements, goals, and the path to attain them, must be clear to the child. Therefore, a *PAL Objectives* system has been developed as an integrated module of the *PAL system*. The *PAL Objectives* consists of the *PAL Objectives Model* and various dashboards presenting this model for different user roles. In this paper, we present the design and usability evaluation of the *PAL Objectives Dashboard* for children embedded in the *myPAL app*. We conclude proposing design guidelines for graphical user interfaces (GUI) visualising personalised achievements and learning goals to children.

¹Personal Assistant for a healthy Lifestyle: <http://www.pal4u.eu>

2 BACKGROUND

It is well known that motivation plays a crucial role in the learning process, especially for children [7]. It represents the driver to go behind the merely “doing something” and it is the counterbalance to keep on trying when frustration coming from failures and negative experiences appears, possibly hampering confidence and self-esteem. Motivation is classified as *extrinsic* or *intrinsic* [34]. The former comes as an effect of outside forces, (e.g., prizes or incentives), while the latter comes from within the person who is learning because of personal interests or fun.

Gamification is the usage of game elements in non-game contexts [8] and this has been applied to educational system to circumvent limitations and increase user action. Well known examples of gamification are points, badges and leader-boards, which showed effective in increasing user productivity and effort [10]. These reward strategies are believed to provoke mainly *extrinsic* motivation. However, gamification features can also motivate the user by providing goals, progress, and encouragement [16]. Visualisation of progress may induce the feeling of competence [8], which is an important aspect of *intrinsic* motivation according to the *self-determination theory* (SDT) [35].

Complementary, from educational sciences, it is known that goal-setting, progress feedback and goal attainment enhance motivation [4, 17] and learning gain [3]. While some argue that ownership of goals is important [15], other claim that relevance of the goals predicts motivation [24]. Further, according to Vygotsky's theory on the *Zone of Proximal Development* (ZPD), goals slightly advancing the learners established abilities encourage and advance learning [42].

3 PAL OBJECTIVES DESIGN

The *PAL Objectives* system has been developed to motivate children to complete educational tasks and thereby improve self-management skills by providing relevant, challenging educational objectives and facilitate monitoring of progress. The *PAL Objectives* consists of 1) *PAL Objectives Model* (POM) a knowledge-base of domain specific achievements, learning goals and tasks [18, 31], 2) *pal-Control&Inform* a web-application for collaborative goal-setting and monitoring [31], and 3) *PAL Objectives Dashboard* for children (*cPOD*) displaying personal objectives (i.e., achievements, goals, and tasks) in the *myPAL app*.

3.1 PAL Objectives Model

The dashboards visualise personalised achievements, learning goals and tasks from the *POM*, which consists of a global layer defining domain specific achievements, goals and tasks and relations between them, and a user specific overlay storing progress.

Achievements, learning goals and tasks represent educational objectives on different conceptual levels. Achievements represent challenging, relevant daily live events, such as having a sleepover or attending a birthday party, that require certain knowledge or skills. Achievements may group multiple learning goals presenting a set of skills, knowledge and/or attitudes needed to engage in the event. Learning goals represent the desired end state of specific knowledge, skill or attitude to be attained by a child (e.g., count carbohydrates). Tasks represent actions a child can undertake in the *myPAL app* to

progress on learning goals (e.g., play a carbohydrates sorting game or filling the nutritional diary). Further are specified the relations between objectives such as prerequisites, and other properties such as level and topic. The separation on levels and topics facilitates non-linear learning; a child can progress faster or slower on certain topics which meets the nature of self-management skill acquisition.

Personal achievements and learning goals may be selected from the global knowledge-base via the *palControl&Inform* –contributing tasks are automatically selected based on selected goals. Further, goal-setting is adapted towards the user model. For example, goals are selected matching the device a child used for insulin intake (i.e., pen or pump). Personal progress on each objective (i.e., inactive, attained or active with % completed) is stored on a user specific overlay of the global layer.

The structure of *POM* is domain independent and loosely based on an existing task ontology [25, 41]. Domain specific content has been created in collaboration with diabetes domain experts. The knowledge-base is formalised in an ontology as part of *PALO*, an integrated *PAL* ontology [18].

3.2 PAL Objectives Dashboard

The *cPOD* was designed to display educational contents, and related acquisition path, to the child in an attractive and challenging way. It should provide the child a clear overview of attained knowledge and skills and activities to undertake to advance progress. However, the complex, abstract and interconnected *POM* information showed challenging to present [31]. Therefore, we aimed to organise the information in the *cPOD* as to provide understandable chunks of information and easy navigation between layers of information.

To focus attention to key information, the start screen (Figure 1a) displays only relevant, high-level information [32, p. 67], being the personal achievements with a progress indicator. A green indicator was chosen for the colour's symbolic meaning of success [22, pp. 48]. Active achievements are listed first, followed by those attained. Progress changes may be notified by the avatar.

Layering [22, pp. 146] was applied organising information as to manage the complexity and reinforce relationships between items. More fine-grained information such as included learning goals, and progress values are shown in the achievements pane (Figure 1b) that is opened by clicking on the achievement. The salient difficulty level is adapted to the child's current level of knowledge, adhering to the ZPD. Previously attained levels are displayed at the bottom to facilitate reviewing past progress. All active achievement are shown in a sidebar to ease accessibility, with the selected achievement placed on top and marked because of saliency and to minimise scrolling [28].

Tasks to attain a learning goal are shown in the goal pane (Figure 1c), which is accessible by clicking on the goal from the achievement pane. For each task, an icon visualises the status (i.e., active or done) and type of task (e.g., game, diary). The icons match those of the activities in the *myPAL app* to support recognition and reduce cognitive load [32, p. 81], [22, pp. 132]. The child can choose to start the activity by clicking the task. If so, confirmation [22, pp. 54] is asked by the avatar to avoid accidental, unwanted navigation outside the *cPOD* [32, p. 19-20].

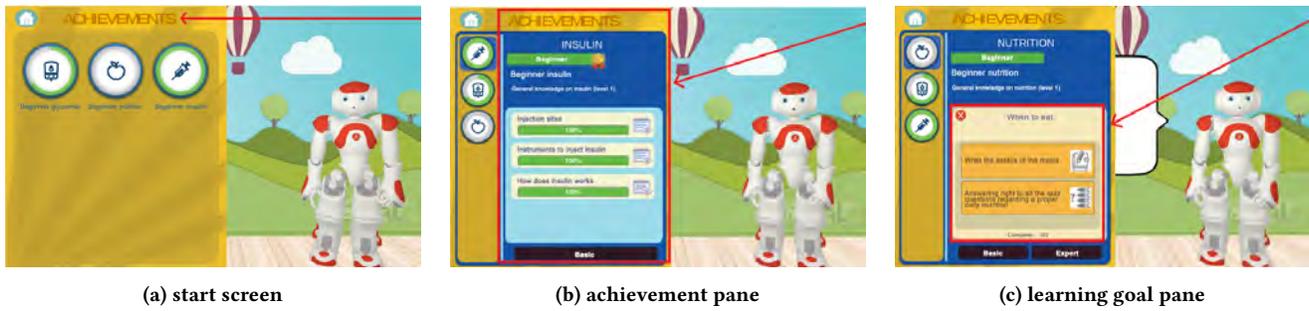


Figure 1: examples of the *myPAL Objectives Dashboard* screens

4 USABILITY EVALUATION

Usability is a quality attribute assessing, from users' perspective, the ease of use of an interface [26] and also refers to qualitative and quantitative evaluation methods to identify any problem while using it [29]. The underlying aim is to remove those interaction problems (e.g., layout, contents, symbols, images) which cause any frustration [38]. However, when dealing with interfaces for children, particular attention has to be paid not only to the design, but also to the usability evaluation methods to be chosen [9]. In fact, children are not simply small adults, but individuals with their own perceptions and communication rules [14].

Method. Following [39], to define the evaluation metrics for the *cPOD*, the *Goal-Question-Metric* (GQM) approach [12] was applied to ISO 9241-11 (1998/2018) usability characteristics of effectiveness, first-time learnability, understandability, and operability. The GQM-model is a paradigm to define and evaluate operational *design goals*, translating them into *questions*, which are quantifiable through both quantitative and qualitative *metrics* [40]. In the present study, we linked the selected usability characteristics (e.g., learnability) to specific *design goals* (e.g., cognitive load) and related *questions* (e.g., “To what extent does a child understand the status of his/her achievements?”) and, lastly, pointed out the corresponding performance *metrics* (e.g., number of errors). A set of task-scenarios were created covering all possible usability aspects highlighted through the GQM. The usability test was structured as *task-oriented*; researchers followed a script guiding the user through the proposed activities, resembling real-life usage of and experience with the *cPOD*. Table 1 depicts a sample of a task and script².

Measures. We took into account both objective and subjective measures: *the error rate*, defined as the number of participants failing usability-task execution, and *participants' verbal responses and researcher's notes* during task execution. These measures were marked on an usability checklist (see Table 2) by a researcher during the test. The checklist included all task-scripts with supposed user actions and predicted errors. Moreover, all screen interactions were recorded with a screen reader.

Participants. A total of 12 children with type 1 diabetes, 8 to 10 y.o., participated in the usability evaluation. Of which six were

Italian (mean age=8.57, std.dev=0.79) and six were Dutch (mean age=9.5, std.dev=0.55), all participating at autumn camps (October 2017) organised in the context of the PAL project by two diabetes patients' associations, which are part of the project consortium. As suggested by [2], a minimum number of eight participants was chosen to reliably reveal possible usability issues.

Materials. In each session we used a Lenovo Tab2 tablet (www.lenovo.com) on which was installed the *myPAL app* 2.0 version, embedding the proposed *cPOD* prototype, and the *AZ*-screen-recorder app.

Procedure. The activities took place at the camp premises. All 12 children participated in the usability evaluation once, individually, and for a duration of maximum 30 minutes. After that the session was ended, regardless of task-script and question completion. During each session a researcher (the *facilitator*) was responsible for all aspects of the study protocol, including initial greetings, guidance through the selected tasks, data collection, assisting and debriefing the participant as shown in Figure 2. At the start of each session the participant received a brief introduction regarding the aim of the study. Then, the child was given a tablet with the *myPAL app* with the *PAL Objectives Dashboard* displaying three predefined example achievements. These achievements were selected to visualise the different possible states: fully attained, active with partial progress, and active with no progress yet (see Figure 1a). Then, the child was asked to go through the *cPOD* and perform and comment on the different usability-tasks.



Figure 2: position of child, tablet and researcher

²To conserve space we provide only one example, the interested reader can find the full task scripts on: <http://www.pal4u.eu/wp-content/uploads/Usability-test-tasks-details-and-results.pdf>.

Table 1: example of a task script and originating GQM

Usability characteristic	Goal	Question	Metric	cPOD location	Task	Script
First time learnability	Cognitive load	To what extent do children understand the display of status of achievements?	Success rate Free comments	start-screen 	Task 3: The user must be able to mention the status of each achievement based on the progress displayed by the circle surrounding each icon.	Looking at the three achievements, can you tell me which is: a) completed, b) partial, c) not completed? Can you tell me how you know?

Table 2: extract of the usability checklist for task 3

cPOD location	Script	Correct	Error	Case	Notes
start-screen 	Looking at the three achievements, can you tell me which is: a) completed, b) partial, c) not completed? Can you tell me how you know this? Do you notice any difference between the three achievements?			1. The child is unable to distinguish between the achievements' status. 2. The child does not notice any difference between the circles surrounding the three achievements.	

5 RESULTS AND DISCUSSION

We counted the error rates from the usability checklists and organised children’s subjective comments (if any), as well as facilitator’s notes or elaborations, through affinity diagrams clustered by Nielsen’s usability heuristics [27].

Consistency and standard issues: “users should not have to wonder whether different words, images, or actions mean the same thing.” Some graphic representations hindered ease of use leading children falsely thinking they were interactive. For example, the green-coloured progress bars in the achievement pane - task 6.6.

Match between system and the real world: “the system should speak the user’s language and follow real-world conventions.” Eight out of 12 participants did not understand that the cPOD was intended to reflect personal achievements activated in collaboration with a health care professional - task 2.1. This might, however, result from using pre-selected achievements for the evaluation rather than actual personal achievements. Further, only half of the children (6/12) understood the detailed information shown in the achievement pane - task 5.1. For example, the achievement label was evaluated as too generic by six participants, misleading them to refer to the overall achievement as to one of the linked goals. Lastly, the corresponding difficulty level, expressed through pre-defined labels (e.g., beginner) were evaluated as unclear by 5 children, who were unable to attribute meaning to it - tasks 5.4/6.

Visibility of system status issues: “the system should always keep users informed about what is going on.” The achievement progress indicator (i.e., a circle surrounding the achievement icon progressively colouring green depending on progress; see Figure 1a) was correctly understood by all participants except one - task 3. Contrary, when exploring the goals for a specific achievement, the highlight indicating in the sidebar the achievement under investigation (i.e., a blue square surrounding the achievement icon; see Figure 1b) was ineffective. In fact, an 83% error rate (10/12 children) was scored in the corresponding task 5.2.

Documentation issues: “it may be necessary to provide help or documentation in the system.” Less than half of the participants were able to explain or point out the list of tasks to do in the myPAL app in order to attain a learning goal - tasks 6.3. Further, none of the children understood ‘their’ current active difficulty level - task 6.4. And only 1/3 understood the next level to proceed - task 6.5.

5.1 Re-design myPAL Objectives Dashboard

The findings presented above informed recommendations improving the cPOD design. These have been implemented in the PAL3.0 System, released May 2018 and currently under evaluation.

Consistency and standard issues: Each goal element is now interactive, the user can click anywhere (description, bar, icon) to navigate to the goal detail-pane - task 6.6.

Match between system and the real world: Once entered in the achievement pane, the section header now reads “My Achievements” to clarify that these are personal achievements to be attained - task 2.1. At the top of the achievement pane is now clearly indicated the current-looked-at-achievement by display of icon, label (short name) and description (full sentence clearly stating the purpose of the objective) - task 5.1. The corresponding difficulty level labels have been rephrased to be more self-explanatory - tasks 5.6. And all possible difficulty levels are presented on top of the achievement pane, with the active level coloured yellow and attained levels green - task 5.4/6.4/6.5.

Visibility of system status issues: When clicking on an achievement to access its details (i.e., view description and goals), now only the achievement pane is displayed, without the list of the other achievements in the sidebar - task 5.2.

Documentation issues: To clarify tasks contributing to goal progress, the task-icon behind each goal is now labelled “tasks”. Clicking anywhere on the goal item will navigate to the goal pane showing the details of the corresponding tasks - task 6.3.

Additionally, some refinements were made to compensate for side effect of other changes in the design. To improve the readability of the information architecture contained in it, the start-screen shows two tabs. The primary tab displays the active achievements, attained achievements are accessible in the second tab. This is meant to ease the navigation in the case of various achievements activated, as to avoid for the children the drawback of having too much scrolling in the page [28]. Further, the achievement pane shows the text “Goals for this achievement” to clarify the meaning of goal-elements depicted right after this text. For each goal-element a full sentence description is given and the progress bar displays the text “*status of completion*” followed by the percentage.

5.2 Discussion

Although the *PAL Objectives* have been developed to optimise children's adherence to the *myPAL app*, the present evaluation was limited towards usability. It is necessary to assure that possible ineffectiveness does not result from usability issues. In fact, if children have difficulties understanding their goals and achievements these are unlikely to motivate them to engage in *myPAL app* activities. To investigate the effect of the *PAL Objectives* on children's motivation using the *myPAL app*, we collect data on perceived user experience and actual system usage. We compare between an ongoing study including the refined *cPOD* and an earlier version of the *myPAL app* presenting objectives in an unsorted list. Preliminary usage statistics, for Dutch participants only, show that average duration of using the *cPOD* increased in the ongoing study (~ 4 min.) compared to the previous version (~ 1 min.). This may indicate that the *cPOD* provided more interesting information and interactions than a simple list of objectives. Comparison with an earlier version of the *myPAL app*, without the sophisticated *cPOD*, may provide some insights towards the usefulness of the *cPOD*. However, possible differences are not necessarily caused by the *cPOD* because many other features of the app were changed in parallel. A controlled study comparing motivation for and usage of an app between a group with and without the *cPOD* is needed to base any conclusion on the effectiveness of the *PAL Objectives* system.

6 CONCLUDING GUIDELINES

The main challenge addressed in the present work is the design of a dashboard to display personalised diabetes self-management educational achievements and learning goals to children in order to increase their usage of a mHealth app. To this aim, an *myPAL Objectives Dashboard* was designed following common interface design patterns and evaluated with diabetic children. The colouring to indicate status was well understood. Children were able to navigate between layers of information, but did not necessarily understand the layered information. Children experienced difficulties interpreting the meaning conveyed in iconic presentations. Based on reported usability issues, we present additional guidelines for the design of a dashboard for children (see Table 3).

Guideline 1: provide descriptive labels. Even though children may tend to not read texts [28], visual elements may not speak enough for themselves. Complementary, clear, short labels can

help a child to understand elements. For example, an icon navigating to task details should be clarified with the label “tasks”. Specifically for complex information structures, such as the *POM*, relations between items must be clarified. For example, by placing descriptive labels before displaying information such as “your current level:” and “goals for this achievement:”.

Guideline 2: connect elements accordingly. When elements are separated their connection is not self-evident. Placing visual elements in close proximity of and in the same ‘box’ as descriptive labels strengthens their connection. For example, placing the icon of the selected achievement inside the achievement pane supports understanding that details of this achievement are displayed. For children, the understandability of the connection between elements (i.e., the icon and details of a single achievement) prevails the need for quick and easy access to other elements (in this case other achievements).

Guideline 3: ease navigation between layers. To avoid cluttering and cognitive overload information needs to be layered and more detailed information should only be given on request. Requesting, however, must be facilitated easily, intuitively, and at the right moment. Moreover, requests that lead to the same information should be given by a single action. In the *cPOD* case, from the achievement pane, for each goal, all sub-elements (i.e., description, progress, task icon, and the box surrounding them) should be interactive and navigate to the goal pane. Further, unclear, cluttering elements such as menu bars should be avoided.

ACKNOWLEDGEMENTS

This work is funded by the EU Horizon 2020 PAL project (grant nr. 643783). We wish to thank all the participating children and the “SOSTegno70-Insieme con i ragazzi diabetici ONLUS” and “Diabetesvereniging Nederland” patient associations for their support.

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Table 3: usability issues and solutions for the cPOD, and derived guidelines for the design of a objectives dashboard.

Identified Usability Issue	Design Refinement	Guideline
(false) Expectation of interactivity of the progress bar	Each goal-element is fully interactive, navigating to goal details	3. Ease navigation between layers
Unaware that personal objectives are displayed	The cPOD heading includes the word “my”	1. Provide descriptive labels
Lack of understanding of achievement information	The achievement pane header shows the icon, label and description The goal are preceded by “goals for this achievement”	2. Connect elements accordingly 1. Provide descriptive labels
Lack of understanding of the level of viewed achievement Lack of understanding of the active difficulty level Lack of understanding of future difficulty levels	All possible difficulty levels for the achievement are listed and coloured according to their status (i.e., green for attained, yellow for active)	Provide all information necessary to interpret meaning
Lack of understanding of the difficulty levels	Revised labels and added colouring	1. Provide descriptive labels
Unable recognise achievements in the sidebar	Removed the sidebar, limit navigation between achievements via the start-screen	3. Ease navigation
Lack of understanding of task information	The task-icon is accompanied with the label “tasks”	1. Provide descriptive labels

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