DR 5.3: Coherent User Experience Recordings

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In this document we report on the work in work package 5 that relates to the recording, structuring and use of user experiences with the PAL system. This deliverable focusses on those aspects of the PAL system that relate to the development of what can be called an artificial episodic memory for the PAL agent, in order to personalize and adapt its functioning to the user, as well as provide a coherent service over time and location (hospital and at home). Parts of the work summarized in this deliverable have already been reported upon in other deliverables (most notable the deliverables from work package 4 and work package 2) as these work packages focus on the strategic use of the data (WP 2) and the data storage format and formalism (WP 4). As such this deliverable is kept succinct on purpose as to not repeat information that has been given already. We focus here on novel developments, and on a coherent view of the activities that have been undertaken in the last period to leverage the data that now can be stored and structured.

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Executive Summary

The work reported upon in this deliverable is focused around coherent user experience recordings. By this we mean collecting, storing and structuring data that is gathered from the children during the usage of the system. Examples of data include time and frequency of logging into the myPal tablet app, usage of health apps in the myPal app, achievement of learning goals, the selection of activities such as the playing of educational games, etc.

This data is stored in a time-enabled RDF database (See also deliverable D4.1) . The data is structured in a ontology that not only defines a place for experience data but also for personalization (e.g., learning goals, a child's preferences). Such personalization data is entered by health care professionals together with the children and parents (see D2.2).

The data is reasoned upon in order to propose possible next actions for the myPal system (app, and (virtual) robot). The reasoning is firstly done with smart rule-based reasoning (WP4, e.g., D 4.1 and D4.2) proposing multiple context-appropriate actions for the robot and system (e.g., the system can propose the child to play a quiz on glucose management). From this set of proposals one is chosen (WP 3, see D3.1 D3.2) and executed by the myPal app and (virtual) robot.

The child then performs an activity, and the data of this interaction is stored in the RDF database, making it available for reasoning upon again. The data is stored in a secure way, and we have also developed a web API to be able to access the data.

Finally, in this deliverable we report upon our work on the scientific investigation of artificial episodic memory. This work focusses on the formalization and computational implementation of an artificial episodic memory that enables a psychologically plausible way of storing associations and appraisal of those associations. This work can in the longer run have a major impact on other domains as well, such as recommender systems and life logging.

Coherent user recordings, storage and data use

For the concrete development of coherent user experience recordings in the PAL project, we have focused on structuring, storing, secure retrieval and reasoning over collected child-robot/system interactions and personal information of the child. For this we developed three things.

Tasks, objectives, results

1.1 Planned work

The work planned for this deliverable relates to Task 5.5. The work has been carried out by many of the partners in good collaboration, and some of it is scattered around other deliverables as well (see exec summary). As such this deliverable provides a focused report of the activities around coherent user recordings. For scientific references see the papers added as Annexes.

We planned to develop "the conceptual and computational structure that is needed to maintain a consistent "whole" for the relation a child has with its PAL". This has been successful. The system effectively maintains, behind a security proxy server with an encrypted API, the current state of the child, the learning goals, the activities, the personalization data, and other data gathered through the use of the myPal system. The reason for wanting this is that "…for PAL to be able to act as a consistent "personality" with the child, it needs to be able to access interaction data (including dialog history, mHealth app stats, achieved health goals, no-verbal affective feedback, engagement). Also, it needs to be able to associate these different kinds of information to each other.". This has been done.

1.2 Actual work performed

We have two parts of the work. The first part relates to the actual developments that enable the system to react in a personalized and coherent way to the child. We refer to this as the *Coherent User Experience Recordings*. The second part relates to fundamental research into what a computational model of episodic memory should look like. We refer to this as *Artificial Empathic Memory*.

Coherent user experience recordings

First, we developed a formal model of the memory of the PAL agent and its interactions with the child as well as the child's interactions with the pall apps. Concretely this means the development of an ontology for the structured storage of learning the child's goals [2, 3], it's interactions with the agent and system, the child's achievements, etc. (See fig 1 for a visual representation of the learning goals). This ontology was developed to be able to relate usage data to learning goals and other child specific data. This enabled us to, for example in WP 4, reason upon next actions for the myPal system based on the current educational need of the child.

Second we developed a database storage structure based on a triple store that also includes time [1], so that actual data can be stored and retrieved. We enhanced the database structure so that that is able to also reason over the collected interactions with the children using the PAL application. This has been developed as part of PAL infrastructure in the form of a RDF-based datastore able to store timed triplets of relations. Concretely this infrastructure is provided by the RDF storage and reasoner HFC, which was developed at DFKI. As already mentioned in former documents, it serves as a uniform information platform that contains the ontology specifications for the diabetes knowledge, the abstract dialogue and information structure, as well as the concrete data (timeline and other user entries, game data, and interaction memory) that is created during the usage of the PAL application. Because all data is additionally annotated with time, it is easy to formulate abstract queries for aggregations over specific time stamps, which strongly supports data retrieval for the episodic memory module.

Third, we developed the technical infrastructure to enable web-based, secure access to this data so that the tablet application and agent can access previous interaction and other child data when the child logs in anywhere anytime. Access to the database has been secured through the use of proxy and data is encrypted. Additional security should be taken for the development of a market ready system, but in the context of the H2020 R&D we have implemented enough for a sufficient proof of concept.

This together provides coherent user experience recordings, as it ties user interaction together with learning goals, progress and reasoning over this data. The coherent user experience recordings are essential for the functioning of the PAL application. It forms the informed basis for the behavior of the agent. For example, it is used to propose particular Quiz activities (see also D2.2) derived from the active learning goals of the child. Also, it is used to generate explanations based on the child's profile (effect of robot action explanation is currently under investigation, but see D2.2 for more on the mechanism explainable AI). Finally it is used to provide insight in the learning progress, and the same coherent recordings can be used to monitor the child's activities by health care professionals (see also D2.1 and D2.2). The work further integrates with work package 4, which is responsible for the development of the RDF structure and reasoning.

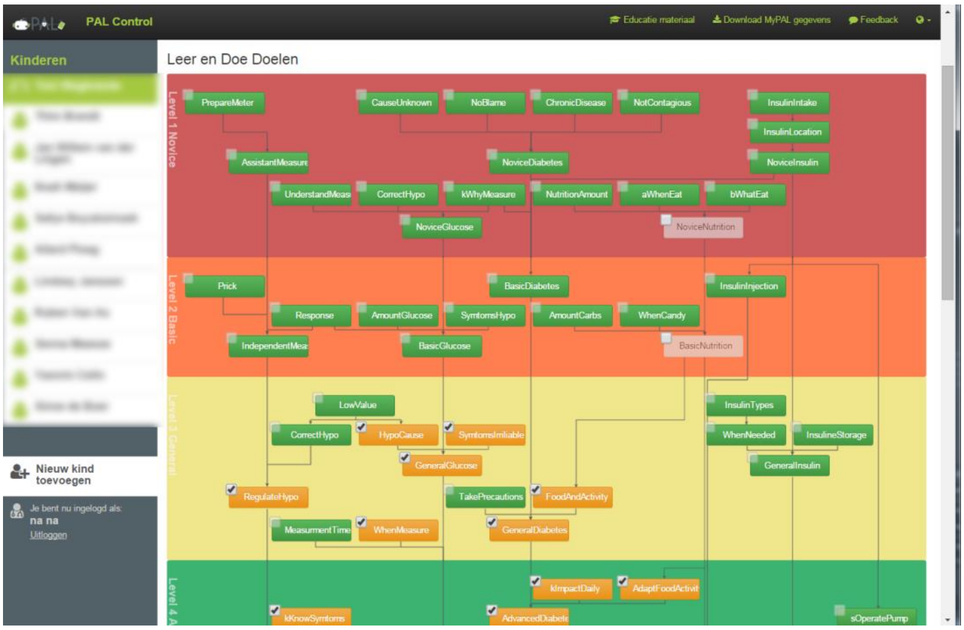

Figure 1. The authoring tool (PAL Control), displaying the diabetes learning goals (i.e., knowledge and skills to attain to progress towards self-management) and achievements with current progress for a 10 year old boy. Attained objectives are green, yellow ones are active. Coloured horizontal bars depict difficulty levels. Topics are arranged vertically.

Artificial Empathic Memory

For the fundamental research into computational encoding of human memories and interactive experiences we have focused on developing a deeper understanding of what it means to model experiences [4]. An essential part of being an individual is our personal history, in particular our episodic memories. Episodic memories are remembered events in someone's past that are typically defined by a time, place, emotional associations, and other contextual information. These events form an important driver for a person's emotional and cognitive interpretation of what is currently happening.

However, current user modeling and personalization technologies are neither aware of how episodic memories are triggered in users, nor of their emotional interpretation of those memories. This is a serious limitation, because it prevents technologies from correctly interpreting the user's current situation. In short, such technologies lack empathy.

Personalization technologies need an *Artificial Empathic Memory* (AEM) of the user to address this issue. We have worked on a psychologically inspired architecture (Fig 2), and we examine the challenges to be solved, and we highlight how existing research can become a starting point to overcoming these challenges (see Annex 4; see Annex 5 for an earlier first version).

To summarize our activities, we have developed a computational architecture for an Artificial Empathic Memory, that enables (when implemented) simulation of the occurrence and consequences of episodic recollections from the perspective of their users. The basis of this model is the realization that experiencing memories is like appraising internally generated events. However, one is not always open for such internal events, because attention is very often directed to the task a person is doing. As such an important first element in our model is the detection attention, or *flow.* Second, we need to know how to decide the association strength with the situations that are stored for the individual and the current situation. This is needed to decide which of stored episodes in the model are most likely to be remembered by the individual too. For this we need to model what is called *ecphoric processing,* the ability to associate one thing with another. Third, we need to *appraise the memory* as this is the emotional interpretation of the memory and colors the experience. An overview of the architecture is presented below. A paper is under submission.

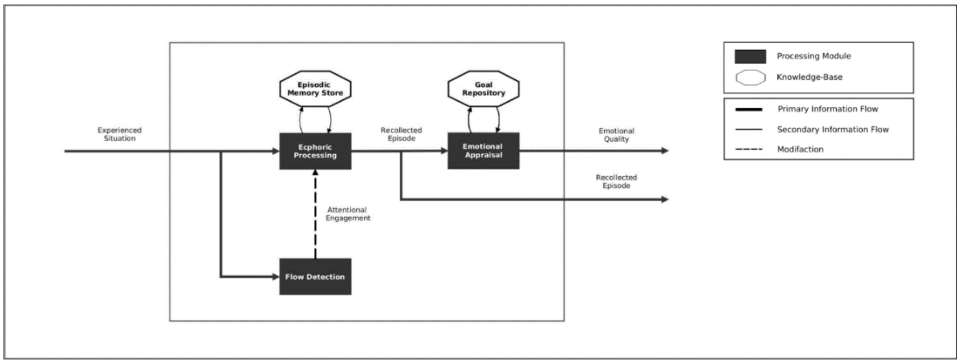

Figure 2. Artificial Empathic Memory overall architecture.

Conclusion, relation to milestones and feedback

With regards to the develeopment and research on coherent user recordings and artificial episodic memory, we have reached our planned goals. The PAL system is able to function as intended, and we have shown significant scientific progress on the topic as well.

References

1. Hans-Ulrich Krieger and Thierry Declerck, An OWL Ontology for Biographical Knowledge. Representing Time-Dependent Factual Knowledge, Proceedings of the First Conference on Biographical Data in a Digital World 2015.
2. Rifca Peters, Joost Broekens, Mark Neerincx, Guidelines for Tree-based Learning Goal Structuring, IUI 2017, March 13-16, 2017, Limassol, Cyprus.
3. Neerincx, M., Kaptein, F., van Bekkum, M., Krieger, H. U., Kiefer, B., Peters, R., Broekens, J., Demiris, Y., & Sapelli, M. (2016). Ontologies for social, cognitive and affective agent-based support of child's diabetes self-management. Artificial Intelligence for Diabetes, 35.
4. Bernd Dudzik, Joost Broekens, Hayley Hung, Mark Neerincx, Artificial Empathic Memory: Enabling Personalization Technologies to Better Understand User Experience, to be submitted.

Annex 1

An OWL Ontology for Biographical Knowledge. Representing Time-Dependent Factual Knowledge

Bibliography Hans-Ulrich Krieger, Thierry Declerck, 2 Proceedings of the First Conference on Biographical Data in a Digital World 2015, Amsterdam, Netherlands, CEURS-WS.org, 7/2015,

Abstract Representing time-dependent information has become increasingly important for reasoning and querying services defined on top of RDF and OWL. In particular, addressing this task properly is vital for practical applications such as modern biographical information systems, but also for the Semantic Web/Web 2.0/Social Web in general. Extending binary relation instances with temporal information often translates into a massive proliferation of useless container objects when trying to keep the underlying RDF model. In this paper, we argue for directly extending RDF triples with further arguments in order to easily represent time-dependent factual knowledge and to allow for practical forms of reasoning. We also report on a freely available lightweight OWL ontology for representing biographical knowledge that models entities of interest via a tri-partite structure of the pairwise disjoint classes Abstract, Object, and Happening. Even though the ontology was manually developed utilizing the Protege ontology editor, and thus sticking to the triple model of RDF, the meta-modelling facilities allowed us to cross-classify all properties as being either synchronic or diachronic. When viewing the temporal arguments as "extra" arguments that only apply to relation instances, universal biographical knowledge from the ontology can still be described as if there is no time..

Relation to WP. Formal basis for the storage and reasoning used in the PAL system.

Availablity Unrestricted. Available for download (http://ceur-ws.org/Vol-1399/paper16.pdf)

Annex 2

Guidelines for Tree-based Learning Goal Structuring

Bibliography: Rifca Peters**,** Joost Broekens, Mark Neerincx, *Guidelines for Tree-based Learning Goal Structuring*, IUI 2017, March 13-16, 2017, Limassol, Cyprus.

Abstract Educational technology needs a model of learning goals to support motivation, learning gain, tailoring of the learning process, and sharing of the personal goals between different types of users (i.e., learner and educator) and the system. This paper proposes a tree-based learning goal structuring to facilitate personal goal setting to shape and monitor the learning process. We developed a goal ontology and created a user interface representing this knowledge-base for the self-management education for children with Type 1 Diabetes Mellitus. Subsequently, a co-operative evaluation was conducted with healthcare professionals to refine and validate the ontology and its representation. Presentation of a concrete prototype proved to support professionals' contribution to the design process. The resulting tree-based goal structure enables three important tasks: ability assessment, goal setting and progress monitoring. Visualization should be clarified by icon placement and clustering of goals with the same difficulty and topic. Bloom's taxonomy for learning objectives should be applied to improve completeness and clarity of goal content.

Relation to WP. Setting appropriate learning goals is extremely important to give focus and a sense of progress to the child. This needs to be collaboratively, so that the child feels he/she is problem owner. As such a goal setting interface, and a method to then adapt the PAL's system behavior based on these goals, facilitate the learning process.

Availablity Unrestricted. Available for download (https://doi.org/10.1145/3025171.3025188)

Annex 3

Ontologies for social, cognitive and affective agent-based support of child's diabetes self-management

Bibliography Neerincx, M., Kaptein, F., van Bekkum, M., Krieger, H. U., Kiefer, B., Peters, R., Broekens, J., Demiris, Y., & Sapelli, M. (2016). Ontologies for social, cognitive and **affective** agent-based support of child's diabetes self-management. *Artificial Intelligence for Diabetes*, 35.

Abstract The PAL project is developing: (1) an embodied conversational agent (robot and its avatar); (2) applications for child-agent activities that help children from 8 to 14 years old to acquire the required knowledge, skills and attitude for adequate diabetes self-management; and (3) dashboards for caregivers to enhance their supportive role for this self-management learning process. A common ontology is constructed to support normative behavior in a flexible way, to establish mutual understanding in the human-agent system, to integrate and utilize knowledge from the application and scientific domains, and to produce sensible human-agent dialogues. This paper presents the general vision, approach, and state of the art

Relation to WP This paper shows the current progress and vision of the PAL-system. The development of ontologies facilitates the development of strategic goal selection, and normative behavior. Furthermore, the ontologies facilitate mutual understanding between the **different** users and the PAL-agent. This paper shows the high level design of the PAL-system, and how the ontologies support the development and intelligence of this system.

Annex 4

Artificial Empathic Memory: Enabling Personalization Technologies to Better Understand User Experience

Bibliography Bernd Dudzik, Joost Broekens, Hayley Hung, Mark Neerincx, Artificial Empathic Memory: Enabling Personalization Technologies to Better Understand User Experience, to be submitted.

Abstract An essential part of being an individual is our personal history, in particular our episodic memories. Episodic memories are remembered events in someone's past that are typically defined by a time, place, emotional associations, and other contextual information. These events form an important driver for a person's emotional and cognitive interpretation of what is *currently happening*. However, current user modeling and personalization technologies are neither aware of how episodic memories are triggered in users, nor of their emotional interpretation of those memories. We argue that this is a serious limitation, because it prevents technologies from correctly interpreting the user's current situation. In short, such technologies lack empathy. In this position paper, we argue that personalization technologies need an *Artificial Empathic Memory (AEM)* of the user to address this issue. We propose a psychologically inspired architecture, we examine the challenges to be solved, and we highlight how existing research can become a starting point to overcoming these challenges.

Relation to WP. Fundamental understanding of what episodic memory is and how this can be formalized and modelled and then leveraged in computing systems.

Availablity Not yet published

Annex 5

Recalling shared memories in an embodied conversational agent: Personalized robot support for children with diabetes in the PAL project

Bibliography Bart Schreuder Goedheijt. Master's Thesis at KTH Information and Communication Technology Sweden (research internship at TNO, Netherlands). October, 2017.

Abstract The PAL project aims to help children with type 1 diabetes to improve their self-management skills using a social robot and its virtual avatar. It has been challenging to gain a long-term relationship with a robot or virtual character. After the novelty effect wears off, the interest of the user decreases over time. The aim of this project was to explore and develop personalized interactions with the children, using episodic memory to improve the engagement and diabetes self-management. A module was built that could capture and refer to shared experiences between the PAL actor and the child. During an experiment with children, the usage decreased over time after the novelty effect wore off. No increases in affection, motivation and diabetes self-management were found after the implementation of the episodic memory module. The full potential of episodic memory was however untested, as the novelty effect already wore off before the implementation. Further research is recommended in order to assess the benefits of an improved version of the episodic memory update during an A/B test.

Relation to WP. First ideas, model and (partial) implementation of an episodic memory in the PAL system.

Availablity Unrestricted. http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-219620