



## DR 2.1: PAL Control: a prototype authoring tool interface for entering coaching protocols

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In this document we report on those parts of the work done in WP2 that relate to task 2.1. Task 2.1 focuses on the development of the authoring tool for health care professionals. This tool enables health care professionals to set learning goals for children during meetings. It further enables to the health care professional to enter child data including personal data and preferences such as sports and hobbies. The current state is a prototype version that minimally provides information entering functionalities so that the PAL system can be deployed for the first experiment. Three important issues were tackled: how to design the interface (and mechanisms behind) to facilitate easy data entering by a health care professional during an intake conversation, how to support gamification of goal achievement, and, how to formalize learning goals for the child based on the medical protocol in the system and interface.

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## Executive Summary

In this document we report on the work done in WP2, in particular task 2.1. Task 2.1 focuses on the development of PAL Control, an authoring tool for care professionals. This tool enables health care professionals (HCP) to set learning goals for children during meetings. It further enables the HCP to enter child data including personal data and preferences such as sports and hobbies. The current state is a prototype version that minimally provides information entering functionalities so that the PAL system can be deployed for the experiments in the first testing campaign. Three important issues were tackled: how to design the interface (and mechanisms behind) to facilitate easy data entering during an intake conversation, how to support gamification of goal achievement, and, how to formalize the learning goals based on the medical protocols in the system and interface.

Further, work has started on designing style-based human robot interactions. Key insight developed here is that robots in educational settings need to be adapting their interaction style to individual children's learning styles to maximize learning outcome and to maximize a constructive and pleasant experience for the children. Research has started on this and a position paper has been published. Learning style and preferred interaction style of the virtual NAO robot can, in a later stage, also be added to the goals of the authoring tool to steer strategic selection of learning goals (e.g., some children like to achieve learning goals by doing while others prefer to achieve the same goals by thinking), which is why we briefly report upon this here too.

As planned, the authoring interface will be evaluated during the first testing campaign. HPCs will have to start working with the tool and will be interviewed about their experiences with it regarding typical usability aspects as well as their understanding of and opinion about the learning goal gamification mechanisms introduced. The character of this experiment will be a co-design session, rather than a formal experiment. We have chosen to keep the tool as simple as possible, as to elicit needs from caregivers rather than triggering criticism on proposed functionality.

This report is the first deliverable report for WP2.

## Role of the Authoring tool in PAL

The overall idea of the PAL project is to provide the child with a long-term and engaging experience and gamification has been proposed as a method for this. This idea has been embedded into the Authoring tool as well (see below). Authoring tool development is part of task 2.1, work package 2. The authoring tool should facilitate entering data into the PAL system (and viewing data in a later stage), so that the PAL agent can start interacting with the child in a meaningful manner and so that the child can work towards personal goals as set by the HCP. Strategic goal setting is the focus of work package 2. The authoring tool is the care professionals tool to manage this process. The authoring tool (to which we also refer as *PAL Control*) thus contribute to the PAL project by enabling the strategic setting of goals, so that goals can be switched on/off/ and achieved enabling the children and the PAL system to focus on a small subset of the goals to be achieved by the child in the short term. This will be explained in more detail below.

## Contribution to the PAL scenarios and prototypes

The authoring tool prototype will enable care professionals to enter child data and preferences to bootstrap the PAL system so that it can interact in a meaningful and personalized manner using the data entered by the care professional. Further, it enables the care giver and PAL system to propose learning goals to the child. In addition, system usage objectives (e.g., enter glucose levels at least 3 times a day) can be linked to learning goals (e.g., manage glucose level), and achievement of learning goals can thus, in principle, be automatically decided by the system (although this typically will not be done because care professionals might want to keep control over that process). The functionality to enter learning goals and child data is critical for the first long term experiment in year 2.

## Tasks, objectives, results

### 1.1 Planned work

This report was planned to report on the first prototype of the PAL care professional authoring tool, enabling the entering of child data, preferences, and learning goals in an intuitive manner that supports gamification of the learning process. This work is part of Task 2.1. Task 2.1 is more elaborate, also including explanation and visualization and value-based reasoning. Though formally the

latter is part of Task 2.2, value tensions will have to be dealt with in the visualization and explanation work of task 2.1. Work has commence on this, but this is not part of this report and will be reported upon at the end of year 3.

## **1.2 Actual work performed**

We report on three elements of the work in WP2: the development of the PAL control interface, which is the authoring tool for health care professionals, the formalization of the learning goals and how this supports gamification of the learning process, and, the research on style-based robot behaviour.

### *PAL Control: the health care professional authoring tool*

We start with a description of the work on PAL Control. PAL Control is a web application allowing the healthcare professional (HCP) easy access to and modification of child data through a graphical interface. This interface is designed for high affordance and low effort. For example, simply clicking the data will make it editable and editable fields are easily identified by their layout.

The PAL Control interface (see Figure 1) consists of three areas with specific functionality: 1) top menu for navigation to the education management page; 2) side menu for child management; and 3) context depended container for either child view or education management.

On the left side is the *child management*, here the HCP can select an existing child from the list of related patients, or add a new child-user. Selecting the option to *add new child*, – after providing the child’s name – an ‘empty child’ is displayed in the child view; the HCP can stepwise enter the child data. Selecting an existing child-user this child’s data is displayed (and can be edited) in the child view.

The *child view* contains the core functionality of PAL Control. In accordance with the first year requirements, PAL Control enables the HCP to provide for a child some basic information (name, age, gender and relatives) and preferences (hobby, colour and sport). Moreover, Type 1 Diabetes Mellitus (T1DM) self-management goals can be selected. Also included is the – later required – possibility to add and select educational materials.

Basic child information needs to be accessible quickly in order to verify display and manipulation of the desired child-user. Therefore, this information is always presented at the top of the child view. Below, other child data is presented grouped by data type (preferences, education and goals). The goals are expected

to be looked at most frequently and thus shown by default. Other data is available on request of the HCP by selecting the according tab.

The *preference* tab contains three basic child preferences: hobby, sport and favourite colour. These preferences are entered by the HCP and can be used by the PAL Agent to personalize Agent-Child interactions. Personalization, such as out of activity talk (OAT) on a topic of the child's interest is suggested to facilitate bonding, and thereby support long-term interaction. Moreover, knowledge of the child's preferences can be used in functional interaction, such as asking the child (quiz) questions related to his/her sport and glucose management. The *education* tab contains a list of available hyperlinks to relevant T1DM (self-management) education. These hyperlinks refer to materials that might support a child in self-management progression. From this list the HCP can select items to be made available for the child (and/or its parents) through the MyPAL application. (Links to educational materials can be edited or removed from the list on the education page.) The *goal* tab shows a finite list of T1DM self-management goals and PAL system usage objectives, the HCP can select from this list goals to activate for the child and specify the credits earned on achievement.

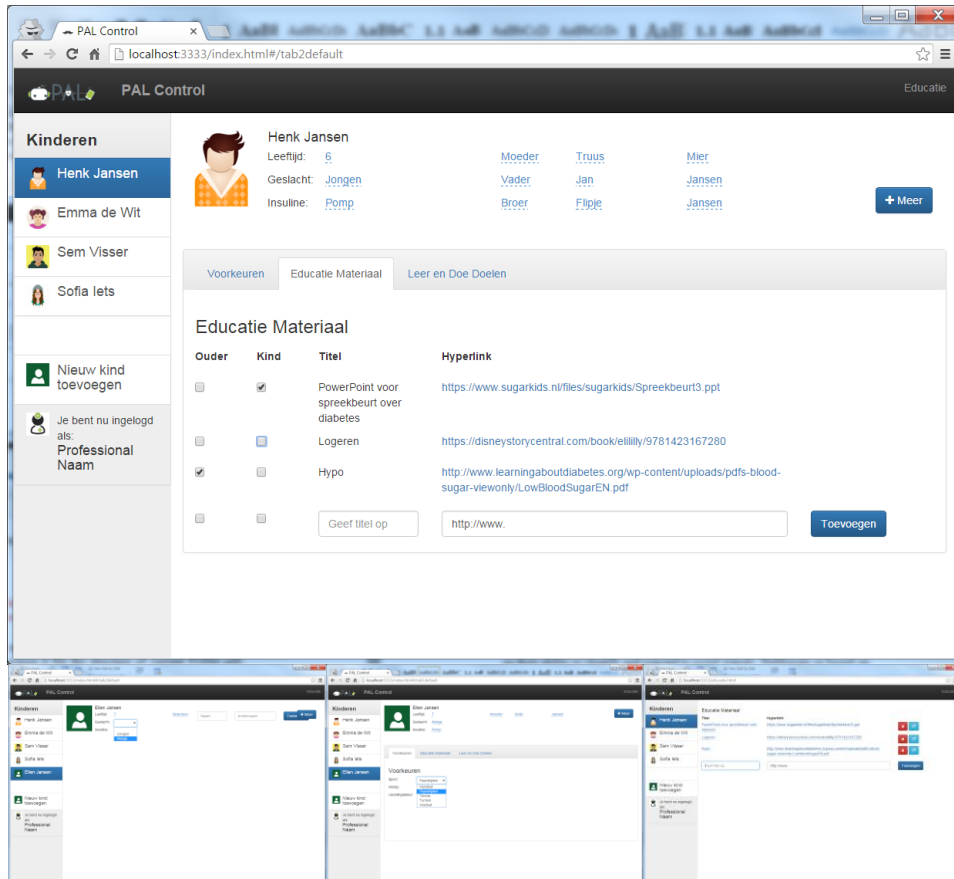


Figure 1. PAL Control interface. Top: child-view of an existing child with the education selection pane active. Bottom from left to right: new child basic information; new child preference; and education management.

### Formalization and gamification of self-management goals

The goals are formalized in an ability-tree (see Figure 2). This tree representation has been chosen for two reasons: it fits the structure of current T1DM self-management education, and, a tree allows for gamification of the process – which is expected to positively influence child motivation. Each node represents an ability needed to be achieved in order to progress down the tree (top-down view is chosen to depict most fundamental goals on top and thus display these initially in the interface). Nodes represent either *knowledge goals*, or *abilities in the PAL* system (e.g., login for the first time) or *abilities in real life* (e.g., insulin injection with a pen). The idea to add PAL system abilities is to motivate the child to work on goal progression by using the PAL system, for example, by playing a game sorting food by high and low carbohydrates and adding the value of the glucose measure before each meal for three days. Other

goals address knowledge and real-life skills needed to be obtained to progress towards full T1DM self-management autonomy and responsibility at adolescence. For example, knowledge on the amount of carbohydrates in foods and being able to perform measurement of blood glucose.

The goals themselves are derived from interview with HCPs and an informal document outlining T1DM self-management education in the Netherlands, provided by the healthcare professionals of the two Dutch hospitals involved (Meander MC and Gelderse Vallei) and discussed also with the doctors of Ospedale San Raffaele. In that document a list of knowledge and skill goals is defined, ordered by subject and age range. The defined goals are to some extent hierarchically ordered: goals can be prerequisites for other goals. Goals relate to a certain subject (food, social, sports/activity, blood glucose and insulin), however, goals might require skills or knowledge from different subjects. Moreover, some subjects – and related goals – might be more or less relevant for a specific child. For example, learning about glucose regulation during sports is mainly relevant for children who exercise on a regular basis or a child who uses a pen for insulin intake, not necessarily needs to learn how to operate a pump.

Nodes can be clicked and toggled off/achievable/achieved. When off they are greyed-out, but still visible. This has been decided to allow children that know the system to actively ask their HCP how they can advance to earn more ability points (see later). When an HCP activates (setting to achievable for a particular child) a node, all prerequisite nodes will be activated as well, the HCP can inactivate (irrelevant) nodes at will by clicking again the selector, such node will then be greyed-out again. Achievement can result automatically from PAL system input (e.g., when the system detects the child played a quiz, the knowledge node for the info in that quiz will become green and an ability point will be available for the child), or through manual registration by the HCP. Such a tree-based structure to structure achievements (skills and knowledge in our case) is often used in popular game genres such as strategy games (e.g. civilization) and role playing games (e.g. the witcher). Upon achievement of a novel goal, the child receives ability points that can subsequently be used to customize the virtual pal agent and to unlock novel content (e.g. games and quizzes). This work is in close relation with the integration and deployment work by Mixel (EU project partner), and inspired by game design principles [1]. The gamification mechanism is thus based on gaining ability points that can be used to customize the system, rather than a levelling mechanism. This allows children to excel at some areas while still needing to learn in others, while a levelling system would require a kid to be at the required level of many skills, which is not in line with personalization of goal setting.



The proposed tree-based formalism for structuring the child's learning process is to be evaluated by the Dutch HCPs and needs validation by the Italian counterpart. Its suitability to structure the learning process will be evaluated in the first experiment in year 2, as planned. This will provide us with interesting data on the potential of gamification of the learning process. This will be done in interviews and co-design sessions with mentioned HCPs.

Child preferences are intended for personalization of interaction and learning, needed for long-term interaction and goal progression. Whereas basic preferences are used to provide some personalized (conversational) content we aim for a personalized learning experience. By providing (in a later stage) more advanced preferences such as coping strategy and learning styles, PAL can adapt to the child needs, to maximize learning outcome and create a pleasant interaction experience. For example, based on preference in learning PAL can favour specific system objectives (e.g. play a game for one child versus reading educational material for another). Although these preferences are learned over time and PAL Agent behaviour should be adaptive, PAL Control can facilitate the HCP to setup initial preferences based on his/her experiences with the child.

#### *Style-based robot behaviour*

We are not only concerned with *what* is an appropriate action, but also *how* this should be communicated. In human-human interaction, educators heavily rely on their ability to identify and respond to social signals. Deliberate or based on implicit competencies, human educators adapt their style of interaction to the learner. For example a teacher can take up different teaching styles e.g. expert or facilitator [2]. These styles are related to the expression of warmth: the expert style is related to low warmth, opposed to high warmth for facilitator style. More open gestures are perceived as high warmth, forward gestures are perceived as low warmth [3]. To test if children can identify robot teaching style, a small pilot was performed at a diabetes camp in the Netherlands in October 2015. The pilot showed that children do seem to notice a difference in style between the robot presenters, however the scale and setup of the pilot does not allow hard conclusions and we are now working on a more formalized experimental campaign to test what behavioural factors of the robot trigger what perceptions of style in children. For more detail on the motivation for this work, we refer to the paper in Annex 2.1.

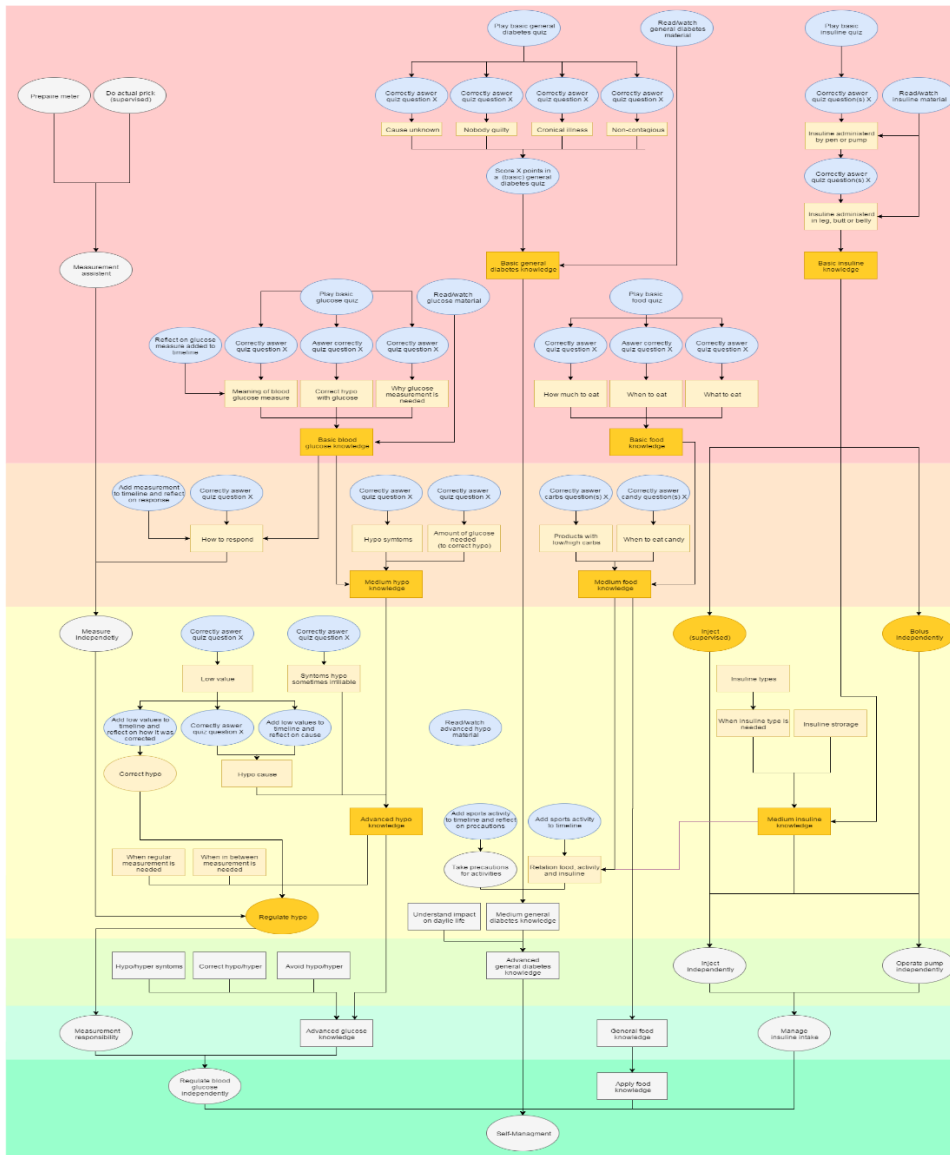


Figure 2. Goal tree. Ovals refer to skill goals to be achieved through the PAL system (blue), e.g., games to play or quizzes to do, or in real life (yellow), e.g. use a pen to deliver insulin. Squares refer to knowledge goals to be learned by the child (always real-life knowledge, hence yellow, dark yellow refers to main achievements in knowledge). Colored bands depict age range, starting at 6-7, increasing by 2 years. Greyed-out are goals not in the first year experiment (but shown to give an overview top the child/care professional).

## References

1. Schell, J., *The art of game design: A book of lenses*. . 2008., Amsterdam: Morgan Kaufman Publishers.
2. Grasha, A.F., *A Matter of Style: The Teacher as Expert, Formal Authority, Personal Model, Facilitator, and Delegator*. *College Teaching*, 1994. **42**(4): p. 142-149.
3. Nguyen, T.-H.D., et al., *Modeling Warmth and Competence in Virtual Characters*, in *Intelligent Virtual Agents: 15th International Conference, IVA 2015, Delft, The Netherlands, August 26-28, 2015, Proceedings*, W.-P. Brinkman, J. Broekens, and D. Heylen, Editors. 2015, Springer International Publishing: Cham. p. 167-180.

## Annex 1

### **Peters et al (2015), “Let Me Guide You! Pedagogical Interaction Style for a Robot in Children's Education”**

**Bibliography** Rifca Peters, Joost Broekens, and Mark A. Neerincx. “Let Me Guide You! Pedagogical Interaction Style for a Robot in Children's Education”. *WONDER workshop at ICSR 2015*.

**Abstract** Social Robots are increasingly applied in healthcare and education. Pedagogical Agents (PAs) are being developed to adapt to the users knowledge, and efforts are made in strategic action selection: what action is appropriate given the context and user preference. However, the issues of how these actions can be appropriately communicated receives less attention. In this paper we propose the development of an adaptive pedagogical interaction style for a robot. We discuss the role of style in human-human interaction and the lack thereof in human-robot interaction. While human educators heavily rely on their ability to identify and respond accordingly to social signals in a fluent and natural way, robots cannot adapt their style of interaction effectively. By adapting the pedagogical interaction style of a robot to the learner and context we expect to be able to create rich and fruitful personalized educational interactions and ultimately facilitate social bonding between the learner and robot. In this position paper we present our view as a starting point for the management of this interaction style. As a basis for the proposition, pedagogic and motivational theories are used.

**Relation to WP.** This publication is a position paper that argues for the need to take interaction style into account when personalizing robots to educate children. This is of direct relevance to WP2, which aims strategically manage learning goals and content using smart technology. Further, knowing how to express particular styles can help children to feel more attached to the PAL agent, thereby facilitating long-term use of the PAL system.

# Let Me Guide You!

## Pedagogical Interaction Style for a Robot in Children's Education

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**Abstract.** Social Robots are increasingly applied in healthcare and education. Pedagogical Agents (PAs) are being developed to adapt to the users knowledge, and efforts are made in strategic action selection: *what* action is appropriate given the context and user preference. However, the issues of *how* these actions can be appropriately communicated receives less attention. In this paper we propose the development of an adaptive pedagogical interaction style for a robot. We discuss the role of style in human-human interaction and the lack thereof in human-robot interaction. While human educators heavily rely on their ability to identify and respond accordingly to social signals in a fluent and natural way, robots cannot adapt their style of interaction effectively. By adapting the pedagogical interaction style of a robot to the learner and context we expect to be able to create rich and fruitful personalized educational interactions and ultimately facilitate social bonding between the learner and robot. In this position paper we present our view as a starting point for the management of this interaction style. As a basis for the proposition, pedagogic and motivational theories are used.

**Keywords:** Social Robots, Child-Robot Interaction, PAL, Healthcare, Education, Pedagogical Agent, Interaction Style.

## 1 Introduction

As robots will emerge in the social and private domain, robots begin to collaborate with humans who are not trained to do so. These socially interactive robots are defined by their ability to express and perceive affect, communicate in high level dialog, learn user models, establish and maintain social bonds, use natural cues, express personality and develop social skills [13]. The importance of social intelligence for robots is stressed, and thereby the need for development of robots able to identify, understand and respond to human communication [17]. Usage of social robots range from assistive robots in elderly care, to tour guides, to educational support. We focus on educational robots, namely, our research is centred around the development of a personal assistant for a healthy lifestyle (PAL) to study long-term child-robot interaction. The (NAO) robot is intended to support children with diabetes mellitus type 1 (T1DM) in extra-curricular self-management education.

According to Mubin et al. [27] an educational robot can, dependent on the content and student, fulfil the role of tool, co-learner or mentor. Moreover, the style of interaction is dependent upon task and user age. In general, educational robots should take into account or adapt to the age and requirements of the learner, suggested is consideration of the learners characteristics such as age, gender and background. [27] We believe that aside these more general attributes, characteristics specific to the educational context should be taken into account. When humans perform educational tasks, they need not only pay attention to the content, but also (unconsciously) select how to communicate the information; they approach the learner in an individual stylized manner (e.g. empathic or direct). The ability to recognize and act upon social cues is crucial for effective and motivating educational interaction. Therefore, social robots employing educational roles should have some kind of interaction style management. We define interaction style as the way in which information is expressed; *how* interaction is formed, displayed by a combination of behaviours that evoke a perceived (NAO) robot intent to influence the user. For example, a request to close the window can be communicated in a comforting, empathic style, expressed through a soft voice, subdued movement and question asking, or by a direct, agitated style, expressed through raised volume, big gestures and statement provisioning. In recent years, pedagogical agents are developed adapting their role to the perceived level of knowledge [7, 32, 19] or affective state of the user [16, 29, 5]. Some have investigated generalized effect of educational strategies on the interaction itself and outcomes such as learning gains [3, 24, 28]. The results of these studies indicate that people are able to detect and respond differently to different robot roles, but little is known about the influence of individual user preferences on these effects. A recent study showed that interaction style could actually influence task performance in collaborative play [8]. A pilot study showed a positive influence of content personalization on enjoyment, motivation, learning effect and interaction intensity [18]. We argue that, for educational robots to become truly personalized, adaptive social collaboration partners, not only affective expression and generalized action selection need to be pursued, but also the personalized and contextualized style of communication aligned to user preferences in learning and interaction needs to be addressed.

In this paper, we propose a model for pedagogical interaction style for educational robots. Based on theory of motivational interviewing and learning style we introduce a pedagogical interaction style that is context sensitive and adaptive to the user model, spanning over long-term usage and seconds. With this approach our future work aims to provide the possibility to create personalized and appropriate robot behaviour supportive to socially intelligent human-robot interaction that facilitates social bonding. The paper is organized as follows. Section 2 provides a brief summary and discussion of the state of the art in social robots and pedagogical agents. In section 3 theoretical background of human-human educational interaction is highlighted. Afterwards, the model for pedagogical interaction style is introduced and exemplarily explained by its usage in PAL. Lastly, concluding remarks are presented in section 5.

## 2 Related Work

In this section we focus on studies and related work from two relevant fields, namely social robotics and pedagogical agents (PA). Although PAs are mostly concerned with virtual presentation of instructional agents, work on modelling and expression of agent behaviour is of relevance to the development of a robot instructor.

### 2.1 Strategic Behaviour Selection and Evaluation

Different perspectives are taken on what is appropriate behaviour, and how this behaviour is to be strategically selected. In recent work, the behaviour of a (virtual) agent is often predetermined based on role or mapped to a perceived user state.

Based on theory of constructivism and zone of proximal development, Smith and Affleck [32] developed a virtual agent to support programming learning, selecting the agents function (*facilitator*, *tutor*, *advisor* or *pseudo-student*) aligned with the perceived level of knowledge. In an interview skill training simulation for police officers, interpersonal stance (degree of dominance and affect) is used to model convincing affective responses for an embodied conversational agent (ECA) [5], evaluation showed that users are able to recognize a persona expressed by the ECA [6].

A virtual and physical (iCat) instructor, designed to support self-help and motivation, fulfilled the roles of a: *buddy* asking about well-being and showing empathy, *educator* informing and asking about health and *motivator* asking about and providing feedback on desired changes [25], no difference in motivation and learning effect was shown in child-robot interaction [24]. In another project children participated in collaborative play with a (NAO) robot designed either as *peer* based on collaborative behaviour or *tutor* based on scaffolding support [35], in difficult tasks the peer condition showed higher task effectiveness and performance compared to the tutor [8].

An attempt to develop an emotional responsive virtual tutor in STEM education is made in AutoTutor [16]. The agent detects typical learner affective state (confusion, frustration, boredom, interest, excitement or insight) and accordingly adapts its action (feedback, pump, prompt, hint, assertion, correct, answer, summarize) to maximize learning effect. Emotional expressions through facial expression, prosody and posture modulation were added to engage the learner in a human-like, natural interaction [11]. Criticism is expressed on the straight forward strategy selection based on learners current affective state, an optimized PA should actively attempt to steer the learner into affective states correlated with positive learning effects and prevent negative once [11]. A field study with an educational (Robovie) Robot learning English to Japanese children showed the robots ability to teach English by informal education [20]. The robot was able to recognise the user and called the user by name to encourage interaction, some positive effects are reported. Interest declined after one week, learning gains were observed for those individuals who maintained interacting in

the second week. The authors suggested that bonding facilitates learning gain, however, it is unsure if maintained interaction is the result of bonding or interest in English learning. Moreover, no comparisons are made with other teaching methods.

## 2.2 Affective Bodily Expression

If we are able to develop a model to select appropriate behaviour, this behaviour must be convincingly expressed by the agent. Up until now, most research has been focusing on emotion modelling and expression.

Human emotion is often expressed through voice, facial expression, gestures and bodily movement [23]. Paiva et al. [30] argue that emotions are essential for interactions that resemble human-human interactions and that appropriate display of affective state positively affects user involvement. Moreover, to be perceived as socially intelligent, the agent must not only convey believable expressions, but also be able to do so in an intelligent and personalised manner by gradually adapting their affective behaviour to the particular needs and preferences of the user [30]. Individuals differ considerably in encoding and decoding of emotional signals, and have different styles preferring certain gestures as well as modalities they use. Current development of ECAs are based on either general trends or averages from multiple individuals [23]. For example, Ball and Breese [2] directly mapped arousal to size and speed of gestures, and valence to voice pitch to generate ECA responses aligned to the emotional state of the user. In EMOTE realization of emotions by shape-effort analysis from Laban movement analysis is proposed [9]. An attempt to capture individual differences by integration of user personality into the ECAs mental state is done in PARSYS [1] and GRETA [26], in the latter the ECAs baseline personality, expressed by default parameters for gestures, is dynamically modified based on communicative intentions of the ECA.

Humanoid robots often have simple faces and thus rely mainly on bodily expression of emotion, which are suggested to be more difficult to decode [30]. However, anger, sadness and joy are reported to have equally accurate recognition rates for facial expression and static posture [23]. An experimental study showed that children can recognise emotion expressed in static robot posture, the following recognition rates are reported: fear (87.5%), happy (89.28%), angry (96.43%), sad (67.86%) and surprised (68.75%) [10]. Affective expression of a social robot by bodily movement in one-to-many interaction is researched in [34] where a humanoid (NAO) robot gave a lecture in an actual course on robotics. Co-verbal gestures of the robot were modulated to express either positive or negative valence. Participants reported no difference in perception of the robot, indicating that participants do not consciously recognize the robot mood. However, the experiment indicated that gesture modulation does influence participant behaviour: self-report for arousal was higher for participants who received a lecture from the positive robot and video annotation showed increased valence and arousal of the audience in the positive mood condition. No effects on task-performance are reported.



### 3 Human-Human Pedagogic Interactions

Human educators heavily rely on, and therefore are trained in, strategic use of interaction style to create effective educational interventions. They continuously adapt their behaviour to the individual needs of the learner and context. In this section we review several theories that underlie this process of adaptation.

#### 3.1 Motivational Interviewing

In healthcare, three communications styles are defined: *directing*, *guiding* and *following*. The directing style is used when giving straightforward advice. A following style can be appropriate to support a patient e.g. during moments of negative emotions. The guiding style is suited for difficult conversations about behaviour change. Three core communication skills are defined: *asking*, *informing* and *listening*. All skills are required for each style, however, their occurrence varies. Moreover, content and phrasing indicate communication style. Motivational Interviewing (MI) [31] can be regarded as refined, goal-oriented form of guiding; counselling aimed at long-time behaviour change by influencing intrinsic motivation for change. The core principle of MI is to understand and evoke the patient's motivation and empowering the patient in behaviour change by exploration of pros and cons of alternatives. The conversation spirit should be collaborative, evocative and honour the patient's autonomy; rapport is used to resolve the patient's ambivalence about behavioural change.

#### 3.2 Experiential Learning Theory

Experiential Learning Theory (ELT) [21] is based on commonly accepted propositions of learning to: be a process, be holistic, require conflict resolution, result from interaction with the environment and is a process of creating knowledge (constructivism). In the ideal process of learning the learner repeatedly progresses through a cycle of: *experience*, *reflection*, *conceptualize & generalization* and *acting on new knowledge*. ELT proposes that the idealized learning cycle varies by individuals' learning style and learning context. Kolb identified four learning styles describing a preference for different phases of the learning cycle: *diverging*, *assimilating*, *converging* and *accommodating*. All people learn best when shifting through different phases, however, learners tend to enter the cycle at a preferred point; the relation between learning style and according preference is depicted in Figure 1a. Learning style is influenced by the learner's personality, but also by environmental factors such as: educational specialization, roles and tasks [22].

#### 3.3 Theory of Multiple Intelligences

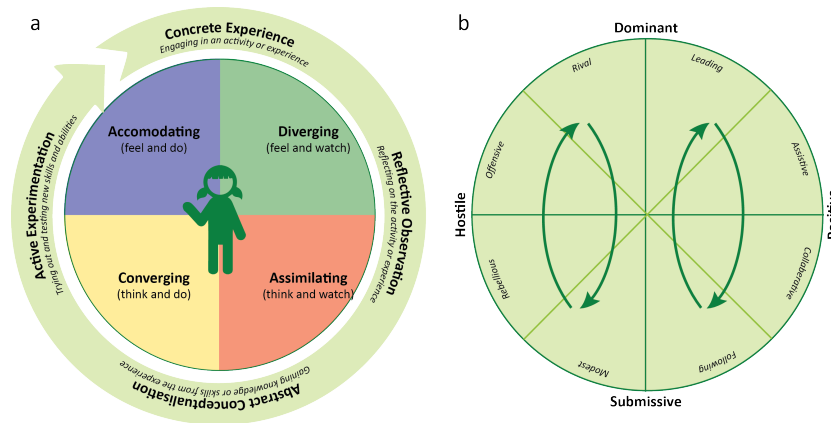
The Theory of Multiple Intelligences (MIT) originally identified seven relatively independent forms of information processing that differentiate in sensory modalities.

ties: *logical-mathematical, linguistic-verbal, visual-spatial, musical-rhythmic, bodily-kinaesthetic, interpersonal-social* and *intrapersonal-self-knowledge* [15]. Gardner suggested that individuals differ in their profile of intelligences and will benefit from education wherein teachers use methodologies and activities to serve all students opposed to only those who excel at linguistic or logical intelligence [14], leading to an increased feeling of engagement and competence. Despite the broad criticism on Gardner's work his theory is adopted in many educational settings and used to describe learning preferences.

**VARK Model.** VARK [12] is an acronym for Visual, Aural, Read/write and Kinaesthetic, it references to the preference learning modality; the way information is presented. This preference is not fixed but stable over medium-term and can be identified by both learner and teacher. Information communicated aligned with preferred modality is likely to result in better understanding, higher motivation and deeper learning.

### 3.4 Leary's Rose

Leary's Rose (see Figure 1b) —also known as the interpersonal circumplex—is a model for human interactional behaviour defined by two axes: *dominance* and *affect*. The horizontal affective-axis depicts willingness to cooperate. The vertical dominance-axis tells to what degree someone is dominant or submissive. The axes divide the rose into four quadrants, of which each half indicating an interpersonal style. Leary's theory states two interaction rules: above-below are complementary and opposed-together are symmetric, meaning that, for example, opposed behaviour evokes opposed behaviour and above behaviour evokes below behaviour [33].



**Fig. 1.** a: Kolb's learning phases and related learning style preferences. b: Leary's interpersonal stances with the direction of interaction rules.

## 4 Adaptive Pedagogical Interaction Style for Robots

To create personalized human-robot interactions the robot must be knowledgeable about the users state and context and have the ability to respond appropriately [4]. In the related work section some advancements on adaptation and strategic behaviour selection are presented. To the best of our knowledge no attempts are made to personalise robot behaviour based on user preference of learning style. For example, AutoTutor adapts to the perceived user emotion, not to learning style preference. What we believe is needed is a) a list (or ontology) of interaction styles, b) a validated way to express these styles in robot behaviour, c) to find out which style is a-priori appropriate (for who and when), and d) adapt the style if metrics (interaction intensity) show we did not select the best/appropriate style for a particular person at a particular moment. In this section we propose a model for adaptive pedagogical interaction styles for educational robots.

We envision a robotic educator who adapts its behaviour to learner preferences and is sensitive to context; based on the user model and contextual factors an interaction style with a high likelihood of appropriateness is selected and expressed, the active choice is continuously evaluated and if necessary adjusted. Continuous evaluation of appropriateness support online adaptation and enables learning over time the user's preferences for interaction style.

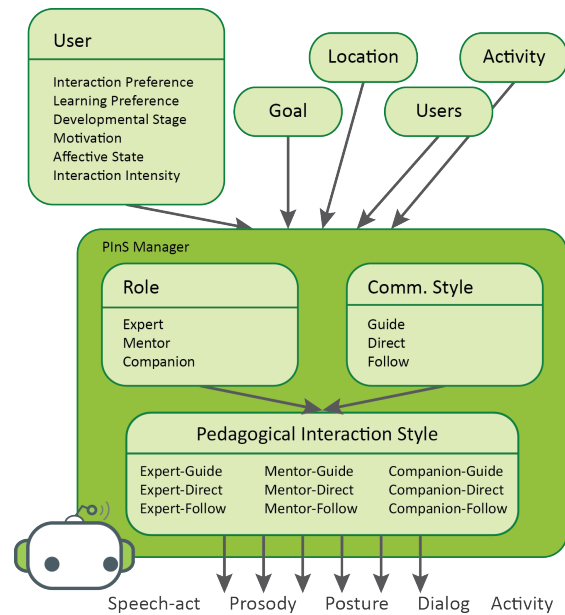
### 4.1 PAL for Children Diagnosed with T1DM

We now explain our approach in more detail by an example in healthcare education for children diagnosed with diabetes mellitus type 1 (T1DM) in need of self-management training.

For the sake the example, we define three educational roles: *expert*, *mentor* and *companion*, and we adhere to the three communication styles presented in [31]: *guide*, *direct* and *follow*. Based on the user model a likely appropriate robot role and communication style are selected; the pedagogical interaction style is defined by the combined selected role and communication style and expressed in the robots behaviour. The user model consists of knowledge of user preferences (e.g. developmental stage, learning style and interpersonal stance) and dynamic perception of the user state (e.g. affective state, interaction intensity and motivation). Moreover, contextual factors such as the current location, users and activity are to be taken into account. Continuous evaluation of the interaction (intensity) is necessary to be adaptive and ensure appropriateness. This implies the system has a memory and is capable of real-time detection of influencing factors. For each interaction style output behaviour is defined; this includes activity selection and expression of style by e.g. speech act, body posture, mood modulation etc. However, contextual factors also have a direct influence on output behaviour; asking a question is never considered appropriate in a classroom setting during a test.

Imagine a child (Robin) aged 7 prior to an important soccer game. Robin surely wants to be on the field, but knows this will only be allow this if the

blood sugar measurement is good. Taking no risks Robin decides to write down a fake measurement. PAL, Robin’s personal support Robot, noticed that Robin changed the values, PAL knows that Robin has a learning goal to manage diabetes during sports, what should PAL do? Having the knowledge that Robin lacks insight in consequences of bad blood values during sports, PAL should educate Robin on this and provide necessary information: the expert role is selected. Guiding is the a priori preferred communication style thus the *Expert-Guide* interaction style is selected and PAL proposes to play an educational quiz. However, PAL notices that the interaction intensity is very low, and believes that Robin is sad; knowing that Robin prefers empathic interaction conveyed in the companion role when feeling sad, PAL changes to the *Companion-Guide* interaction style and starts a conversation about sports asking Robin about his likes and dislikes regarding his illness and soccer. When one of Robins friends enters the room PAL detects this change in users. Robin has a self-management goal to learn to talk about his disease with friends, but because of the perceived negative affective state PAL decides that now is not the right time; PAL obeys to Robins preference, changes to the *Companion-Follow* style and pauses interaction.



**Fig. 2.** Model for management of pedagogical interaction style depicting factors (user, goal, location, users and activity) influencing selection of role and communication style, that together determine which pedagogical interaction style is chosen, which is then expressed in robot behaviour using, for example, prosody, speech and posture. (contextual factors and behaviours are included for illustration purposes only.)

## 5 Conclusion/Discussion

We have argued for the need of educational robots that can adapt their interaction style to individual users. We have reviewed approaches that adapt the robot's role and learning content based on the child's state, but these approaches do not try to measure and adapt to the preferred interaction style of the user. To explain our position, we have shown using an abstract model, how this personalized interaction style could be generated.

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## References

- [1] Badler, N., Allbeck, J., Zhao, L., Byun, M.: Representing and Parameterizing Agent Behaviors. In *Proceedings of Computer Animation*, 133–143 (2002)
- [2] Ball, G., Breese, J.: Emotion and Personality in a Conversational Agent. *Embodied Conversational Agents*, 189–219 (2000)
- [3] Baylor, A. L.: Expanding preservice teachers' metacognitive awareness of instructional planning through pedagogical agents. *Educational Technology Research and Development*, 50(2), 5–22 (2002)
- [4] Bickmore, T., Gruber, A.: Relational agents in clinical psychiatry. *Harvard review of psychiatry*, 18(2), 119–130 (2010)
- [5] Bruijnes, M.: Social and emotional turn taking for embodied conversational agents. In *Proceedings International Conference on Social Computing*, 977–978 (2012)
- [6] Bruijnes, M. and Wapperom, S. and op den Akker, H.J.A., Heylen, D.K.J.: A virtual suspect agents response model. In *Intelligent Virtual Agents*, 17–24 (2014)
- [7] Buche, C., Querrec, R., Loor, P. de, Chevaillier, P.: MASCARET: Pedagogical Multi-Agents System for Virtual Environment. (2003)
- [8] Charisi, V., Lohse, M., Zaga, C., Evers, V.: Report on user behavior. (2015)
- [9] Chi, D., Monica C., Zhao, L., Badler, N.: The EMOTE Model for Effort and Shape. In *Proceedings of Computer Graphics and Interactive Techniques*, 173–182 (2000)
- [10] Cohen, I., Looije, R., Neerincx, M.: Child's recognition of emotions in robot's face and body. In *Proceedings HRI* (2011)
- [11] D'Mello, S., Graesser, A., Picard, R. W.: Toward an affect-sensitive AutoTutor. *IEEE Intelligent Systems*, 22(4), 53–61 (2007)
- [12] Fleming, N., Baume, D.: Learning Styles Again : VARKing up the right tree! *Educational Developments*, 7(4), 4–7 (2006)
- [13] Fong, T., Nourbakhsh, I., Dautenhahn, K.: A survey of socially interactive robots. *Robotics and Autonomous Systems*, 42(3–4), 143–166 (2003)
- [14] Gardner, H. E.: *Intelligence Reframed: Multiple Intelligences for the 21st Century*. Perseus Books Group (2000)
- [15] Gardner, H., Hatch, T.: Educational Implications of the Theory of Multiple Intelligences. *Educational Researcher*, 18(8), 4–10 (1989)
- [16] Graesser, A. C., Chipman, P., Haynes, B.C., Olney, A.: AutoTutor: an intelligent tutoring system with mixed-initiative dialogue. *IEEE Transactions on Education* 48(4), 612–618 (2005)

- [17] Heerink, M., Krse B., Wielinga, B. Evers, V. : Human-Robot User Studies in Eldercare: Lessons Learned In proceedings of international conference on smart homes and health telematics, 31–38 (2006)
- [18] Henkemans, O. A. B., Bierman, B. P., Janssen, J., Neerincx, M. A., Looije, R., van der Bosch, H., van der Giessen, J. A.: Using a robot to personalise health education for children with diabetes type 1: A pilot study. *Patient education and counseling*, 92(2), 174–181 (2013)
- [19] Janssen, J. B., van der Wal, C. C., Neerincx, M. A., Looije, R.: Motivating children to learn arithmetic with an adaptive robot game. In *Social Robotics*, Springer Berlin Heidelberg, 153–162 (2011)
- [20] Kanda, T., Hirano, T., Eaton, D.: Interactive Robots as Social Partners and Peer Tutors for Children : A Field Trial. *Human-Computer Interaction*, 19, 61–84 (2004)
- [21] Kolb, D. A.: *Experiential learning: experience as the source of learning and development*. New Jersey: Prentice Hall (1984)
- [22] Kolb, A. Y., Kolb, D. A.: *The Kolb Learning Style Inventory. Experience Based Learning Systems* (2005)
- [23] Lhommet, M., Marsella, S. C.: Expressing Emotion Through Posture and Gesture. In *The Oxford Handbook of affective computing*, 273–285 (2015)
- [24] Looije, R., Neerincx, M. A., de Lange, V.: Children's responses and opinion on three bots that motivate, educate and play. *Journal of Physical Agents*, 2(2), 13–20 (2008)
- [25] Looije, R., Neerincx, M. A., Cnossen, F.: Persuasive robotic assistant for health self-management of older adults: Design and evaluation of social behaviors. *International Journal of Human Computer Studies*, 68(6), 386–397 (2010)
- [26] Mancini, M., Pelachaud, C.: Distinctiveness in multi-modal behaviours. In *proceedings of autonomous agents and multiagent systems*, 159–166 (2008)
- [27] Mubin, O., Stevens, C. J., Shahid, S., Mahmud, A. Al, Dong, J.: A REVIEW OF THE APPLICABILITY OF ROBOTS IN EDUCATION. *Technology for Education and Learning*, 1, 2090015 (2013)
- [28] Nalin, M., Bergamini, L., Giusti, A., Baroni, I., Sanna, A.: Children's perception of a robotic companion in a mildly constrained setting. In *IEEE/ACM Human-Robot Interaction* (2011)
- [29] Nourbakhsh, I. R., Bobenage, J., Grange, S., Lutz, R., Meyer, R., Soto, A.: An affective mobile robot educator with a full-time job. *Artificial Intelligence*, 114(1), 95–124 (1999).
- [30] Paiva, A., Leite, I., Ribeiro, T.: Emotion Modelling for Social Robots. In *The Oxford Handbook of Affective Computing*, 296–419 (2015)
- [31] Rollnick, S., Miller, W. R., Butler, C.: *MOTIVATIONAL INTERVIEWING IN HEALTH CARE: Helping Patients Change Behavior*. New York, London: The Guilford Press (2008)
- [32] Smith, T., Affleck, G., Lees, B., Branki, C.: Implementing a generic framework for a web-based pedagogical agent. In *Annual Australasian Society for Computers in Learning in Tertiary Education Conference*, Brisbane, Queensland (1999)
- [33] Verstegen, R., Lodewijks, H.: *Interactiewijzer Analyse en Aanpak van interactieproblemen in professionele opvoedingssituaties*. (1999)
- [34] Xu, J., Broekens, J., Hindriks, K., Neerincx, M.: Effects of Bodily Mood Expression of a Robotic Teacher on Students. *International Conference on Intelligent Robots and Systems*, 2614–2620 (2014)
- [35] Zaga, C. and Truong, K.P. and Lohse, M. and Evers, V.: Exploring child-robot engagement in a collaborative task. In *Proceedings of the Child-Robot Interaction* (2014)