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Linking serious game narratives with pedagogical theories and pedagogical design strategies

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Abstract Narrative-based serious games present pedagogical content and interventions through an interactive narrative. To ensure effective learning in such kind of serious games, designers are not only faced with the challenge of creating a compelling narrative, but also with the additional challenge of incorporating suitable pedagogical strategies. Therefore, development teams must consist of a multidisciplinary group including storytellers, technical staff and pedagogical experts to make sure that suitable pedagogical strategies are incorporated into the narrative. In this paper, the authors show how the Domain Specific Modeling Language ATTAC-L, for modeling the narrative of a serious game, allows creating the link between the processes of pedagogical design and narrative modeling by means of an elaborate annotation system. As such, this modeling language enables different experts to concentrate on the aspects related to their field of expertise without losing oversight of the serious game as a whole. More in particular, we will show how the annotation system can be used to document and integrate the use of a well-grounded pedagogical theory, Social Cognitive Theory, for achieving the goals of a serious game, as well as when the serious game is part of a program developed by means of a well-grounded design strategy, Intervention Mapping Protocol.

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Introduction

Serious games that provide a narrative context are generally more effective at conveying knowledge and achieving behavior change. This claim is supported by the empirical findings of several studies on effective game design (for an overview see: Dondlinger 2007). Therefore, serious game designers often choose to present pedagogical content and interventions through an interactive narrative. To ensure effective learning in such a serious game many factors are crucial. Designers are not only faced with the challenge of creating appealing graphics and a compelling narrative, but also with the additional challenge of incorporating suitable pedagogical strategies into their narratives. In this paper we concentrate on the task of combining a compelling interactive narrative and well-grounded pedagogical strategies into an effective serious game, which creates a few challenges of its own.

A first challenge arises with the need for input from various experts: game designers and developers as well as pedagogical experts and subject-matter experts. Each type of expert adds a different set of expertise to the development process: subject-matter experts bring in their knowledge about the subject of the serious games (such as cyber-bullying), pedagogical experts share their knowledge on how to ensure the learning that is aimed for (like knowledge acquisition, attitude change, and/or behavior change), while storytellers, game designers and developers contribute their expertise on how to design and develop a challenging game. Because each group of experts focuses on what needs to be done from a different perspective—determined by their respective domains of expertise—and often uses a specific jargon to discuss it, the collaboration often suffers from some form of communication barriers. These barriers can seriously hinder the proper development of the serious game (De Troyer and Janssens 2014).

A second challenge relates to the lack of evidence on how to construct serious games that are effective from a pedagogical point of view. While computer games have been around for over 30 years, academic research in this domain scarcely reports on empirical findings related to games and learning (for an overview see Connolly et al. 2012; Ke 2016). Furthermore, literature that presents theories and clear and consistent guidelines on how to incorporate pedagogical principles and techniques into game narratives is scarce (Catalano et al. 2014).

In previous publications, we have argued for the use of a Domain Specific Modeling Language (DSML) to support the participation of experts with limited computer engineering background in the specification of (narrative-based) serious games (see Van Broeckhoven and De Troyer 2013, 2014). A DSML is often visual in nature and its syntax uses the vocabulary of the domain under consideration (Kelly and Tolvanen 2008). We proposed and developed such a DSML, called ATTAC-L. This language allows pedagogical and subject-domain experts to specify pedagogical content and strategies and integrated them seamlessly into the interactive narrative of a serious game. It combines flow chart principles with a natural language-based syntax to facilitate the participation of non-computer engineering experts in the specification of narrative-based serious games. The output generated by the DSML is a formal specification that can be processed automatically to generate (parts of) the code for the game.

Thus far, our publications have mainly focused on the visual representation of the DSML and its natural language-based syntax (see Van Broeckhoven and De Troyer 2013; Van Broeckhoven et al. 2015). In these publications, we proposed a mechanism of pedagogical annotations to include details about aspects of the employed pedagogical strategy in the narrative of a serious game. These annotations are specified on top of the storyline and allow the modeler to associate pedagogical issues, such as pedagogical objectives and actions, with particular parts of the story. This way, modelers (and other stakeholders) can easily and clearly identify which parts of the storyline attribute to specific pedagogical objectives and how particular pedagogical interventions are incorporated into the storyline.

In this paper, we move ahead by examining *how* existing pedagogical theories and design strategies can be incorporated in serious game narratives with the help of the annotation system of ATTAC-L. More in particular, we will show how this can be done for a well-grounded pedagogical theory, Social Cognitive Theory (SCT), and a well-grounded design strategy, Intervention Mapping Protocol (IMP).

SCT is a learning theory based on the idea that human learning can take place through both direct and vicarious experiences (Valcke 2005). This means by a process of observational learning. Video games are very well suited to support vicarious learning experiences as well as behavior rehearsal, which are both corner stones of SCT. The principles of SCT have been used in different serious games. Examples are “Escape from Diab” (Thompson et al. 2010) and “Reach Out Central” (ROC) (Burns et al. 2010).

IMP has been developed to aid in the systematic planning and design of behavioral change programs and can therefore be used as a method to identify and design suitable pedagogical interventions. IMP has already been successfully applied for the development of serious games and digital intervention platforms, for example: “PR:EPARe” (Positive Relationships: Eliminating Coercion and Pressure in Adolescent Relationships) (Arnab et al. 2013), and “The Gay Cruise” (Kok et al. 2006) and “QueerMasters” (Mikolajczak et al. 2008) (both intervention programs addressing HIV-prevention in the Dutch homosexual community). Although the latter two are not explicitly presented as serious games, they are similar in the sense that they use virtual narratives in which the characters introduce the participants to the issues at hand.

The paper is structured as follows: “Related work” section discusses related work. “ATTAC-L” section briefly describes ATTAC-L. “Linking narrative and pedagogy” section discusses how the modeling concepts of ATTAC-L and the annotations in particular can be used to link the narrative and the pedagogy of a serious game. We show this in the particular case of SCT and IMP. “Conclusions and future work” section presents conclusions and future work.

Related work

In the context of serious game development, researchers have emphasized the importance of building on the foundations of proper pedagogical strategies (Kiili 2005; Kirkley et al. 2005; de Freitas and Oliver 2006; Kickmeier-Rust et al. 2006; Göbel et al. 2009; Steinkuehler et al. 2012; Beatty 2014; Baalsrud-Hauge et al. 2015; Arnab and Clarke 2016). Unfortunately, guidelines on how to successfully adopt such an approach in the design process are scarce and mostly formulated at a high level of abstraction. Gunter et al. (2006), for example, identify three major educational theories that align closely with the design principles that are generally accepted among game developers and games researchers, namely: Bloom's Taxonomy (Bloom et al. 1956), Keller's ARCS Motivational Model (Keller 1983) and Gagne's Events of Instruction (Gagne 1985). The authors combine these theories to create the RETAIN model for serious game design. However, this model provides no practical guidelines for implementing the theories in serious game design, nor does it provide means to document the actual application of the model in the design process.

Only a small number of researchers have elaborated on the practical implications for serious game design when building on particular educational theories. In "Mapping learning and game mechanics for serious games analysis", Arnab et al. (2015) identify a broad set of essential learning mechanics as well as important game mechanics. The authors present a concept map, called the LM-GM model that indicates the relationships between learning mechanics and actual game mechanics. According to the authors, the LM-GM model is merely a method for analyzing and suggesting game mechanics to stimulate deeper learning. The LM-GM model provides no means for documenting how learning mechanics are employed inside the game to realize high-order pedagogical objectives. Therefore, Carvalho et al. (2015) proposed an extension of the LM-GM model based on concepts from Engeström's Activity Theory (Engeström 2001). The results is the Activity Theory-based Model of Serious Games (ATMSG), which enables developing teams to specify the relationships between the components of the serious game and its educational objectives. The list of learning components in ATMSG is composed of learning actions, learning tools, and learning goals. The learning goals are based on Bloom's Updated Taxonomy (Anderson and Krathwohl 2001), Kolb's Experiential Learning Cycle (Kolb 1984), and Fink's Taxonomy (Fink 2003). Despite the common intentions to specify how particular game elements support learning, our approach is complementary to the ATMSG approach, as it focuses on providing tool support for the design phase following the analysis phase. Our approach is not limited to a particular pedagogical theory, but can be fitted to accommodate any desired theoretical framework or strategy. ATMSG remains primarily focused on the analysis and understanding of how learning can take place through games.

Furthermore, various authoring tools have been created for designing scenario-based serious games, such as interactive digital storytelling tools: StoryTech (Göbel et al. 2008), Scenejo (Weiss et al. 2005), e-Adventure (Torrente et al. 2010). Additionally, several DSMLs have been developed for the same purpose, such as

WEEV (Marchiori et al. 2011) and GLiSMo (Hirdes et al. 2012). Most of these systems concentrate on one aspect, which is often the storyline of the game. More interesting with respect to our own work, are the authoring tools that also aim to integrate educational strategies into the narrative by explicitly linking pedagogical design principles to particular elements of the narrative. EDoS (Environment for the Design of Serious Games) (Tran et al. 2010) is such an interactive authoring environment for serious games. Its purpose is similar to ours: is to help an interdisciplinary team in designing a serious game by offering a number of standardized steps: from the point of formulating the pedagogical objectives, to the point of elaborating a scenario and modeling user interactions. The outcome of following these standardized steps is "a structured scenario that will be automatically executed by an engine." (Tran et al. 2010, p. 393). EDoS focuses on the reuse of available components of different granularity and the creation of serious games for teaching engineering skills. The design process of EDoS builds on 3 models. The first one is a model of the targeted pedagogical objectives (for example: professional competences for an engineer). The second model relates pedagogical objectives and pedagogical activities in order to construct pedagogical scenarios for serious games. These scenarios are created using an adapted version of the IMS-LD (Instructional Management Systems—Learning Design) (Koper and Olivier 2004) language, which only describes the pedagogical content of the serious game. The third model helps to include the entertaining elements, or the task model that describes the screens with which the users will interact. In contrast with our approach, the EDoS approach relies on a specific learning design, namely IMS-LD and thus provides limited flexibility. Furthermore, publications related to EDoS do not provide guidelines or methods for identifying pedagogical objectives or constructing serious game scenarios.

ATTAC-L

ATTAC-L is a Domain Specific Modeling Language for specifying the storyline of educational video games. It combines a syntax based on a controlled natural language with flow chart modeling principles to allow both technical and non-technical people to model (or to describe in a formal way) the narrative of an educational video game (Van Broeckhoven et al. 2015). The output, a formal specification of the game narrative, can be processed automatically to generate parts of the code for the serious game. Note that ATTAC-L does not aim to replace the creative process of devising a compelling narrative; it focuses on the specification of the narrative and allows to complement it with pedagogical and engineering oriented specifications. Neither does ATTAC-L aim to deal with the artistic process of creating appealing graphics and animations.

A first basic modeling concept in ATTAC-L is the *game move*, which stands for a single action in the narrative (Lindley 2005). It represents one individual step in the game narrative, either performed by the player or by a non-playable character (NPC). A story is formed by denoting the relative order of the game moves. For this, ATTAC-L adopts principles from flow-chart modeling (for example, activity diagrams of the Unified Modeling Language (UML)). The modeler can express *sequence* (game moves following each other), *choice* (branching or defining alternative story flow paths), and *concurrency* (story flow paths that are performed in parallel). In addition, ATTAC-L provides an extra control mechanism to increase its expressiveness; *order independence*. This mechanism allows modelers to indicate that particular story flow paths must all be performed but regardless in what order.

A second important modeling concept is the *brick* (adopted from the StoryBricks framework[1]). Bricks are the basic graphical building blocks used in ATTAC-L to represent the game moves as well as the overall flow. Two classes of bricks are therefore distinguished: *regular bricks* and *control-bricks*.

Regular bricks are used to construct game moves. A brick is used to represent the smallest meaningful unit that exists in the context of a story. This can be an act to be performed, a tangible object that can perform or undergo the act, a state, or a value. Game moves are constructed by interconnecting bricks according to rules based on a controlled natural language. The result is a construct that reads as a simple sentence and denotes a game play activity; the game move. A regular brick is graphically represented by a rectangle containing a word or word-group that gives it a meaning. In Fig. 1, the white rectangles containing words are regular bricks. As can be seen, the bricks are combined to form simple sentences; the game moves. For example, in Fig. 1a, they are:

"`Nate| goes-to| Player`"

and:

"`Nate| says| 'Ah, there you are. (I've) been looking for you. You've seen what Bill did? Don't think that's right. Where's Vic? Let's go find him!'`"

(For details about constructing game moves, see Van Broeckhoven et al. 2015).

Control bricks are used to express temporal relationships between game moves. As stated earlier, ATTAC-L uses a flow-based structure for this because empirical evidence shows that this is more suitable for non-technical users than, for instance, the use of state diagrams (Van Broeckhoven and De Troyer 2013). Because the target users may not be familiar with the typical flow-chart notation used in modeling languages such a UML, we have decided to use bricks as well to represent these control structures. In Fig. 1, the grey bricks that interconnect game moves are control bricks. We distinguish bricks to model sequence, choice, order independence and concurrence. A sequence-brick is represented as a chair-like brick that interconnects game moves. In Fig. 1a, it is used to specify the order between two game moves, so that Nate first goes to player after which he says "Ah, there you are …" to player. A choice-brick encapsulates alternative storyline paths. Figure 1b shows a choice for the player between saying "Yeah, right I suppose" or "Yeah, definitely true! That was really lame!" Similarly, an order independence-brick encapsulates storyline paths that must all be performed, but in any order. Figure 1c

[1] http://www.storybricks.org (project discontinued since 03-05-2015).

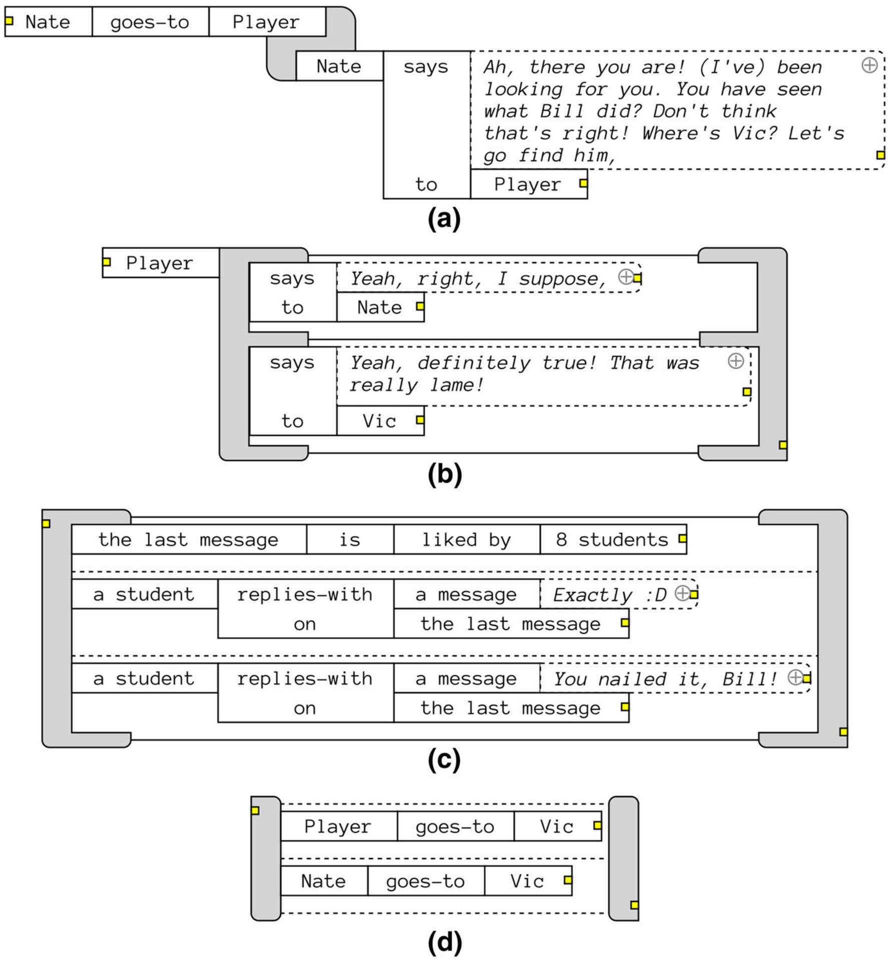

Fig. 1 Several ATTAC-L control structures (fragments taken from Fig. 6)

expresses that 8 students will like the message and one will reply with "Exactly: D" and one with "You nailed it, Bill", but the order in which they do it is irrelevant. Finally, a concurrence-brick encapsulates storyline paths that are performed in parallel. Figure 1d specifies that both the player and Nate go to Vic at the same time.

A third modeling concept is called *scenario*. This concept is introduced to deal with the complexity of large models. It allows designers to divide a large narrative into smaller logical units and represent such a unit as a scenario. A so-called scenario-brick can be used to refer to a scenario and can be used like other game moves in a storyline. Figure 4 shows a storyline using scenarios. The overall scenario "Introduction to Comforting", contains two sequential scenarios "Vic's bullying situation" and "Nate demonstrates comforting", each represented by a scenario-brick (shown at the top of the example), and connected by a sequence-brick. This means that first the scenario “Vic’s bullying situation” is performed, next the scenario “Nate demonstrates comforting”. The scenarios themselves are defined further down in the model.

The fourth modeling concept in ATTAC-L is the concept of *annotation.* It enables the modeler to specify additional information and interventions (for example, pedagogical relevant information and interventions or important visual aspects of the environment) to related parts of the storyline model (Van Broeckhoven and De Troyer 2014). Annotations allow adding those aspects on top of the storyline model. This prevents that the specification of different aspects of the serious game are entangled. In case of pedagogical annotations, it allows for a clear separation between the narrative content and the educational aspects, while the modeler can still relate the pedagogics to the story flow. Annotations are represented graphically by means of small and square-like bricks, called annotation-bricks. Each annotation-brick contains an icon that indicates its type. Different types of annotations have been predefined (explained further down). Annotation-bricks can be attached to game moves and to scenarios. Figure 5 shows the scenario from Fig. 4 with annotations. When clicking on an annotation brick in the ATTAC-L tool, its content will pop up (see Fig. 5). The structure of the content of an annotation depends on its type. Some examples are given below.

Currently, ATTAC-L distinguishes between *pedagogical annotations* for specifying pedagogical related aspects and *gameplay annotations*, such as *scene annotations* for specifying aspect related to the game environment (such as indicating a change of the scene), and *NPC annotations* for specifying aspects related to a NPC (such as emotions that should be expressed or behavior that should be displayed). However, this annotation system is extensible and new types of annotations can be added as needed for the case under consideration, for instance annotations to indicate specifications related to the interaction device(s). In this paper we concentrate of the pedagogical annotations (PA). PAs are currently further divided into *action PA*, *objective PA*, *pedagogical theory PA*, and *method PA*:

- *Action PAs* are used to specify particular pedagogical oriented actions that should be performed in the story, such as providing additional information, assistance or feedback, that is, they are concrete pedagogical interventions.
- *Objective PAs* are used to explicitly relate pedagogical objectives, such as learning goals or behavioral change objectives to scenarios or parts of the story. An example of such an objective would be “to know the multiplication tables of 1–10” or “to understand the impact of cyber-bullying”.
- *Pedagogical theory PAs* are use to indicate the underlying pedagogical theory used to achieved the pedagogical objectives (such as behaviorism or constructivism). They are usually attached to a complete story model or to scenarios.
- *Method PAs* are used to specify the particular pedagogical methods or instructional design models used to reach particular pedagogical objectives in the story or in scenarios. Examples of such methods are drill & practice, trial and error, problem-based learning, or learning by doing. Since many different methods are possible—each with different characteristics—this annotation type is an abstract one, which means we cannot define all of its properties

(comparable to an abstract class in UML). Concrete subtypes can be defined for different methods. For instance, the *role-modeling PA* has been defined for the "modeling" or "observational learning" principle used in the Social Cognitive Theory (SCT) (Bandura 1991).

An overview of the current annotation classification system is given in Fig. 2.

Linking narrative and pedagogy

As already explained, the annotation system of ATTAC-L allows expressing the connections that (should) exist between the narrative and the pedagogical strategy developed to achieve the objectives of the serious game.

As each learning theory and each pedagogical design strategy has its own principles, it is not possible to provide a single recipe for integrating their principles into a serious game. Therefore, we present for two cases, the pedagogical theory

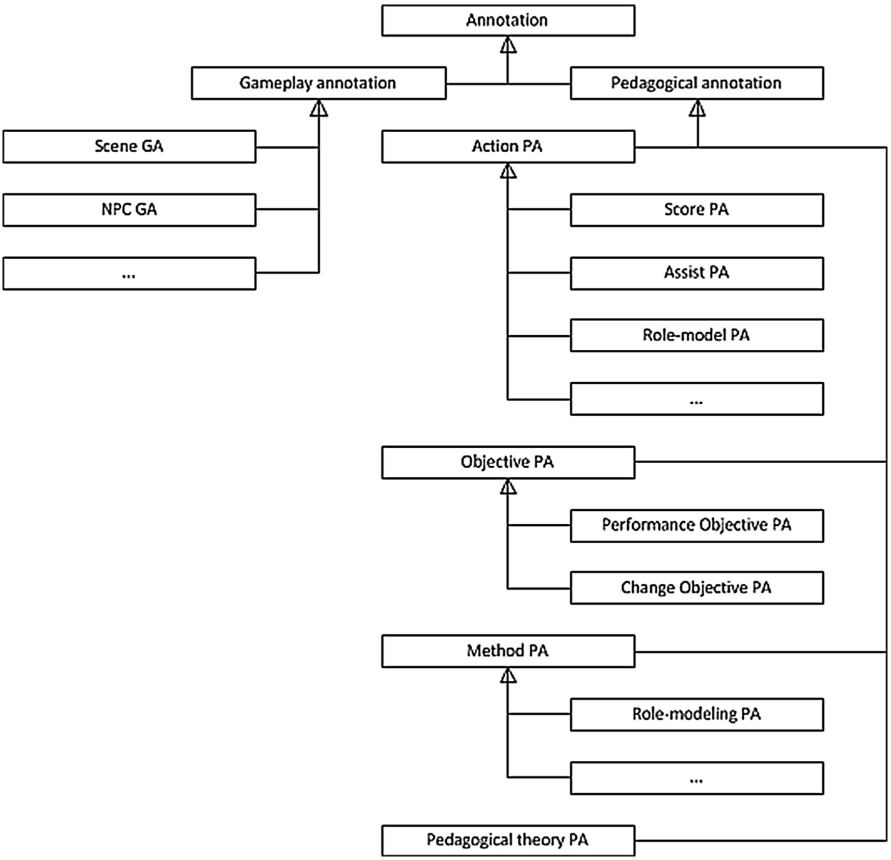

Fig. 2 Annotation class-hierarchy

Social Cognitive Theory (SCT) and the pedagogical design strategy Intervention Mapping Protocol (IMP), how the annotation system of ATTAC-L can be used to specify the relationship between the narrative and the pedagogical strategy and how to integrate the pedagogical strategy into the narrative. Note that the two approaches can be combined, as the intervention methods derived by a particular design strategy will in general be based on one or more pedagogical theories. We will illustrate this in the examples given. The context of our examples is the Friendly ATTAC project (2012), which aimed to develop a behavioral change program for youngsters about cyber-bullying and which was developed using IMP. One of the program goals was to teach youngsters how to react in an adequate way when confronted with cyber-bullying incidents.

The Social Cognitive Theory (SCT) case

SCT

Albert Bandura, the intellectual father of Social Cognitive Theory (SCT), describes learning as a cognitive process "in which information about the structure of behavior and about environmental events is transformed into symbolic representations that serve as guides for action." (Bandura 1986, p. 51). Furthermore, Bandura stipulates that learning is also a social process, whereby people's mental models are developed and modified through social influences in the form of modeling, instruction and social persuasion (Bandura 1989, p. 3). This translates into SCT's central premise, which states that people develop expectations, beliefs and self-perceptions—in other words, mental models—on how to act in a particular context by observing, listening and interacting with others. Through this social and cognitive process, people develop "a working model of the world that enables [them] to achieve desired outcomes and avoid untoward ones." (Bandura 2001, p. 7).

The concepts of "modeling" and "vicarious experiences" are crucial within SCT. In fact, various researchers have found that "virtually all learning phenomena resulting from direct experience can occur vicariously by observing people's behavior and its consequences for them." (Bandura 1989, p. 21; see also: Rosenthal and Zimmerman 1978; Hergenhahn 1988; Slavin 1994).

SCT distinguishes four main processes that are involved in all kinds of socially-guided learning: attentional, retentional, production, and motivational processes.

Attentional processes determine how much people observe and what they are able to extract from the learning experience. A learner's attentional process can be influence by many factors, including: prior knowledge (Bandura 1986) and personal characteristics like perceived self-efficacy (Gage and Berliner 1975), as well as the attractiveness and functional value of the model's behavior (Valcke 2005).

Retentional processes relate to the acts of transforming and restructuring information of models into rules and concepts that can be easily retained or memorized by the learner.

Production processes refer to the process of translating symbolic representations of "models" into a suitable course of action. These processes involve: organizing, monitoring, comparing and correcting action sequences in light of the available mental models (Carroll and Bandura 1985, 1987).

Motivational processes determine if the learned behavior will be performed. According to SCT, there are three main types of motivators: direct, vicarious and self-produced incentives (Bandura 1989). Direct incentives relate to the directly experienced cost and benefits of particular actions, while vicarious incentives refer to those cost and benefits observed in the behavior of others and its consequences. Self-produced incentives relate to people personal standards, beliefs and perceived self-efficacy. Bandura points out that the latter is particularly important as "the likelihood that people will act on the outcomes they expect prospective performances to produce depends on their beliefs about whether or not they can produce those performances." (Bandura 2001, p. 10).

In light of SCT, a number of recommendations have been formulated with regard to the design of educational environments (for an overview, see Valcke 2005). In order to increase attention processes, the learning environments should provide clear and interesting cues and incorporate rewarding and punishment schedules to sharpen the learners' attention. Furthermore, models should showcase their high status, as well as their skills and expertise in determining what is important in the learning situation to attract the attention of the learners. In order to increase retentional processes, learners should be provided with early feedback and ample opportunities to practice and rehearse. The latter also applies to the increase of the production processes, as the learning environment should provide learners with the possibilities to "imitate" or even surpass the behavior of the model. Finally, to increase the motivational processes, the learning environment should frequently and sufficiently offer various types of incentives that increase the chances of actual performance of the learned behavior.

Serious games incorporate many learning principles that closely align with the ideas and guidelines of SCT (see, for instance, the learning principles present in video games as identified by James Paul Gee (2003)). While other media, such as movies or books, can provide observable models, games "provide entire worlds designed to help learners adopt roles and engage story lines previously inaccessible to them. If properly designed, they can provide the problems, tools, people, experiences, perspectives, and consequences to ensure that learners develop rich content understanding." (Barab et al. 2010, p. 525; see also Barab et al. 2009).

Using SCT in a narrative

Various principles of SCT can be used in serious games to achieve (some of) the objectives of a serious game, but to do so requires a translation of these principles into serious game constructs. In general, a pedagogical principle can be embedded in a story-based serious game in two ways. On the one hand, it can be embedded (1) as game mechanics that are complementary to the storyline and support the player's learning in a specific way. For example by presenting a pop-up to the player with extra hints or by awarding points after making a correct choice. On the other hand, pedagogical principles can be embedded in a serious game (2) as events expressed directly in the narrative, for example by using a character that demonstrates the correct behavior, or by giving positive feedback during an in-game conversation.

ATTAC-L allows modelers to specify that a principle is realized by a particular game mechanic (method type (1)) by using *action PAs*. Recall that action PAs are used to express required actions that have a particular pedagogical intention, such as providing additional information, assistance, or feedback. Different subtypes of action PAs have already been defined, like the *score PA* that changes a player's score and the *assist PA* that gives hints to the player.

Pedagogical principles can also be embedded in a serious game by expressing them as a part of the narrative (method type (2)). In this case, the modeler should annotate the scenario containing the intervention based on the particular principle as a whole by means of a *method PA* or one of its subtypes.

In order to explain in more detail how specific principles of SCT can be translated and integrated into a narrative using our annotation system, we use the storyline models given in Figs. 5 and 6 as illustrations.

Integrating the modeling principle to create vicarious experiences and guided-instruction In a serious game, the modeling principle described by SCT can be achieved by introducing one or more so-called role models in the game. This can be a character that actively participates in the story and demonstrates the intended behavior (higher named method type (2)), but it can also be a kind of buddy that offers on-demand help and advice to the player (higher named method type (1)).

In the first instance, method type (2), the modeling principle is integrated in the narrative to create a vicarious experience. The specific part of the story that represents the vicarious experience should be annotated with the *role-modeling PA* (a concrete method PA). This is illustrated in Fig. 5. The complete scenario "`Nate demonstrates comforting`" is used to create such a vicarious experience. Therefore the complete scenario is annotated with a role-modeling PA. This annotation specifies the NPC that play the role-model (here Nate) by means of its attribute "who", as well as the pedagogical objectives that the modelers want to achieve with this role modeling (attribute "objectives"; here the objectives are referred by means of their abbreviations "K1" and "K2").

In the second instance, method type (1), the modeling is achieved by means of direct interaction between the player and the NPC that represents the buddy. These are considered as pedagogical related game actions. Therefore, action PAs should be used to specify them, more in particular the *role-model PA*. This annotation is attached to a game move and specifies how the NPC is fulfilling his role as model for that game move. For instance in Fig. 6, in the scenario "`Posting a picture`", there is a role-model PA specifying that Nate (being the role-model) should tell the player how he would react to the situation.

Supporting learning sub-processes To support the attentional, retentional, production and motivational processes identified by SCT when designing serious games, we propose to follow the recommendations formulated by Valcke (2005). ATTAC-L offers support for this as follows:

- To provide clear and interesting cues, modelers can use pedagogical actions complementary to the storyline models. This can be specified by action PAs: the *inform PAs* to give contextual information, *the emphasis PAs* to put visual cues or emphasis on certain game entities, or *the thought PAs* that can be associate with options in choices. Examples of such action PAs can be found in Fig. 5.
- To incorporate rewarding and punishment schedules, modelers can use the *score PA*. This annotation enables them to specify how certain scoring systems inside the game need to be updated in accordance to the outcome of particular actions in the storyline. Scores can be associated to the player as well as to NPCs and it can be indicated which objectives they serve. An example of a score PA can be found in Fig. 6.
- To provide early feedback to the learners, modelers can use the *assist PA* or the *inform PA*. See Fig. 6 for an example of an assist PA.
- To provide ample opportunities to imitate the behavior of the model, to practice and to rehearse newly acquired behavior, modelers can use the *rehearse/retry PAs*. These PAs enable modelers to mark parts in the storyline that can be rehearsed or be retried. In Fig. 6, the beginning of the scenario "`Posting a picture`" is annotated with a start-rehearse/retry PA (represented by a) to indicate that the player should be able to retry this part of the storyline in case he opts for the wrong choice (ignoring the message) (indicated by the end-rehearse/retry PA (represented by a)).
- To offer various types of incentives that increase the chances of actual performance of the learned behavior, and to do so frequently and sufficiently, we recommend that the modelers integrate them directly into the narrative.
- To showcase of high status, skills and expertise through social learning models inside the game, the modeler depends on the decision regarding the type of integration method (type (1) or (2)). If the role model is implemented as a game mechanic (such as a buddy) on top of the story, then showing its status, skills and expertise should also be implemented in this way. However, if the role model is integrated in the narrative as an active NPC, then showing its status, skills and expertise should also be part of the narrative.

Expressing the learning objectives *Objective PAs* can be used to link scenarios or parts of the storyline with the pedagogical objectives that the modelers intend to achieve through the serious game. For instance, in Fig. 5 the scenario "`Introduction to comforting`" is annotated with two (*change*) *objective PAs*, expressing that the scenario is aiming to achieve the objectives "Describe ways to comfort a victim that are in line with your personality." and "Recognize that by comforting the victim, you are making the victim feel better." Note that also action PAs can be linked to learning objectives as an action PA includes a parameter that allows denoting the targeted objective (see for instance the action PAs in Fig. 6).

Expressing the theoretical foundations ATTAC-L also accommodates meta-level annotations. In this way, the modelers can indicate that the underlying pedagogical theory is SCT by attaching a *pedagogical theory PA* to the storyline or to the corresponding scenarios (if only parts of the storyline are based on this theory). In Fig. 5 the scenario "`Introduction to comforting`" is annotated with a pedagogical theory PA expressing that the scenario is based on SCT.

Annotating the storyline with a pedagogical theory PA, objective PAs, and action PAs has also the important advantage that it helps modelers to document the underlying pedagogical approach for the serious game in a detailed and formal way.

Intervention Mapping Protocol case

IMP

IMP has been developed to aid in the systematic planning and design of behavioral change programs. The protocol stimulates an ecological approach to the design of behavioral change programs focused on health issues (Sallis et al. 2008). The aim of IMP is to increase the efficacy of the design process as well as the intervention program itself. It does this by means of a set of six clearly defined steps which include iterative cycles of reviewing evidence of problem-related determinants, selecting and implementing theory based strategies, and consulting stakeholders (Bartholomew et al. 2011). IMP encourages its users to document the design process and to create detailed descriptions of the foundations and different steps of the intervention. As such, the protocol also meets the recent and popular demands for more thorough reporting.

IMP outline IMP consists of the following steps: needs assessment, preparing matrices of change objectives, selection of theory-informed intervention methods and practical strategies, development of the intervention program, planning for adoption, implementation and sustainability, and development of an evaluation design.

Step 1 Needs assessment

The first step in IMP is to define the program goal or health problem(s) that the intervention will tackle. This includes identifying the population at risk and developing an understanding of their environmental context. The program goal is refined into program objectives. Each of these objectives is defined in terms of a desired outcome and has a priority. The priorities are set based on the objective's level of relevance, desirability, changeability, as well as the required means and efforts to achieve it (Bartholomew et al. 2011).

Step 2 Preparing matrices of change objectives

This second step comprises an investigation of the behaviors that can help to reduce the problem and attain the program objectives. In the literature related to

IMP, the term *performance objective* is used to refer to the desired behavior. For each of the performance objectives the program designers must assess which factors influence the performance of the desired behavior. Based on this assessment, *behavioral determinants* are identified. What needs to be changed in relation to these determinants in order to achieve the performance objectives is then formulated in terms of *change objectives*. These change objectives create the basis for the development of the actual intervention steps. For each performance objective, the determinants and change objectives are formulated in a matrix of change objectives. Table 1 shows and example fragment of such a matrix for a program to decrease cyber-bullying. The performance objective considered is "always comfort the victim". Behavioral determinants are "knowledge", "self-efficacy", "outcome expectation", and "social norms". For each of these determinants, the change objectives are given. For example, for the determinant "knowledge" the following change objectives should be targeted: "K1: Recognize that by comforting the victim, you are making the victim feel better." and "K2: Describe ways to comfort a victim that is in line with your personality."

Step 3 Selection of theory-informed intervention methods and practical strategies

During the third step, different methods are selected from a body of available literature and assessed in light of the change objectives. This means that for each of the change objectives, the program developers try to find a method that has been tested and said to impact the type of behavioral change that they intend to achieve (Bartholomew et al. 2011). These are then matched with other methods to form practical strategies.

Step 4 Development of the intervention program

In this fourth step, all information of previous steps is combined to develop a so-called Intervention Plan. Information from step 4 is also used to revise decisions made in step 3.

Table 1 Example of matrix for performance objective "always comfort the victim", determinants and change objectives

Performance objective: PO—Always comfort the victim	
Knowledge	K1—Recognize that by comforting the victim, you are making the victim feel better
	K2—Describe ways to comfort a victim that are in line with your personality
Self-efficacy	Se1—Express confidence in being able to comfort or provide advice to the victim
Outcome expectancies	Oe1—Expect that by comforting the victim, he/she will feel better
Perceived social norms	Sn1—Recognize that your friends expect you to comfort or provide advice to the victim

Step 5 Planning for adoption, implementation and sustainability

Although listed as step 5, implementation planning runs throughout the whole development process. To ensure that the finished product would be feasible to use in practice, a group of stakeholders (often including teachers, schools, school counselors and youth advisory centers) is set up at the onset of the project to provide feedback.

Step 6 Development of an evaluation design

Similarly, step 6 runs throughout the whole development process. This step covers the evaluation of the intervention program, which is performed by conducting formative research and assessing effectiveness together with end users.

IMP for the development of serious games

IMP allows for the systematic planning and design of behavioral change programs. A serious game could be part of such a program as a way to accomplish the performance objectives, though it may still be useful to complement it with other components, such as media campaigns, lectures, and lessons. The serious game should then be designed (as part of step 4) to target the associated change objectives using identified intervention methods and practical strategies (in step 3). The implementation of the serious game is part of step 5, while its evaluation is part of step 6. Note that step 6 actually runs throughout the whole development process, which is in line with good software engineering practices. IMP is also in line with a user-centered software development approach given the incorporation of stakeholders (Göransson et al. 2003).

Linking narrative and IMP outcome

When a serious game is part of a program developed with IMP (in step 4), the serious game should target one or more of the change objectives associated with the performances objectives (outcome of step 2) while using intervention methods and practical strategies identified in step 3 of the IMP process.

Linking the outcome of the IMP process—the performance objectives, change objectives, and intervention methods—to the narrative creates two important advantages: first, it allows the designers to verify whether the serious game and the IMP outcomes are in accordance with each other; secondly, it provides automatically documentation of the design process as required by IMP.

To illustrate our approach for linking the outcome of the IMP process to the narrative, we use the storyline models given in Figs. 3, 4 5 and 6. As already indicated, the context of our example is the Friendly ATTAC project (Friendly ATTAC 2012), which aimed to develop a behavioral change program for youngster

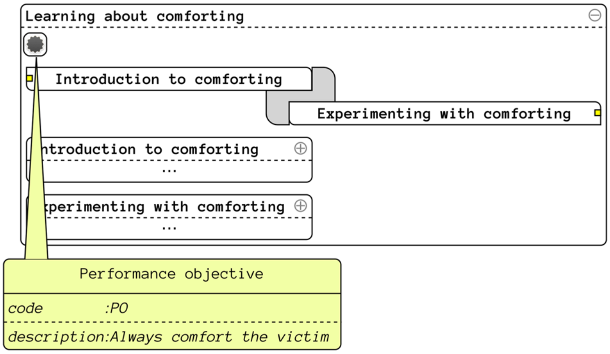

Fig. 3 A scenario with a performance objective "always comforting the victim" and two sub-scenarios (both detailed in Figs. 5 and 6)

about cyber-bullying and which was developed using IMP. The scenario that we use here focuses on the performance objective PO described as "comforting a victim after witnessing a cyber-bullying incident". Using IMP, the behavioral determinants and change objectives associated with this performance objective were identified in the *matrix of changes objectives* (see Table 1—we refer to the work of our colleagues (DeSmet et al. 2016) for more details about the IMP program developed), as well as a set of intervention methods.

We start by explaining how to link the performance objectives and their further refinement into change objectives to the storyline. We then do the same for the techniques and strategies of the intervention methods.

Linking IMP objectives Objective PAs are used to specify which part of a storyline model is associated with a particular performance objective and change objectives. To support the distinction between performance objectives and change objectives used in IMP, we have extended the default annotation system with two new annotations, both subtypes of the objective PA: *performance objective PA* and *change objective PA*. A performance objective PA has a parameter that identifies the IMP performance objective. See Fig. 3 for an example, the IMP performance objective is "always comfort the victim" (defined in Table 1).

A scenario annotated with a performance objective PA can be divided into different sub-scenarios, each dealing with one or more of the change objectives of the performance objective and their corresponding behavioral determinants. To reflect this, sub-scenarios are annotated with change objective PAs to indicate with which specific change objectives they are dealing. The sub-scenarios of the scenario "`Learning about comforting`" used in Fig. 3 are "`Introduction to comforting`" (elaborated in Fig. 5) and "`Experimenting with comforting`" (elaborated in Fig. 6). The first one is annotated with change objectives related to the determinant "knowledge" (see Fig. 5). This implies that the scenario should contain intervention methods specifically for increasing the knowledge of the player about comforting a victim. The second sub-scenario focuses on the determinants "outcome expectations" and "perceived social norms" and has two change

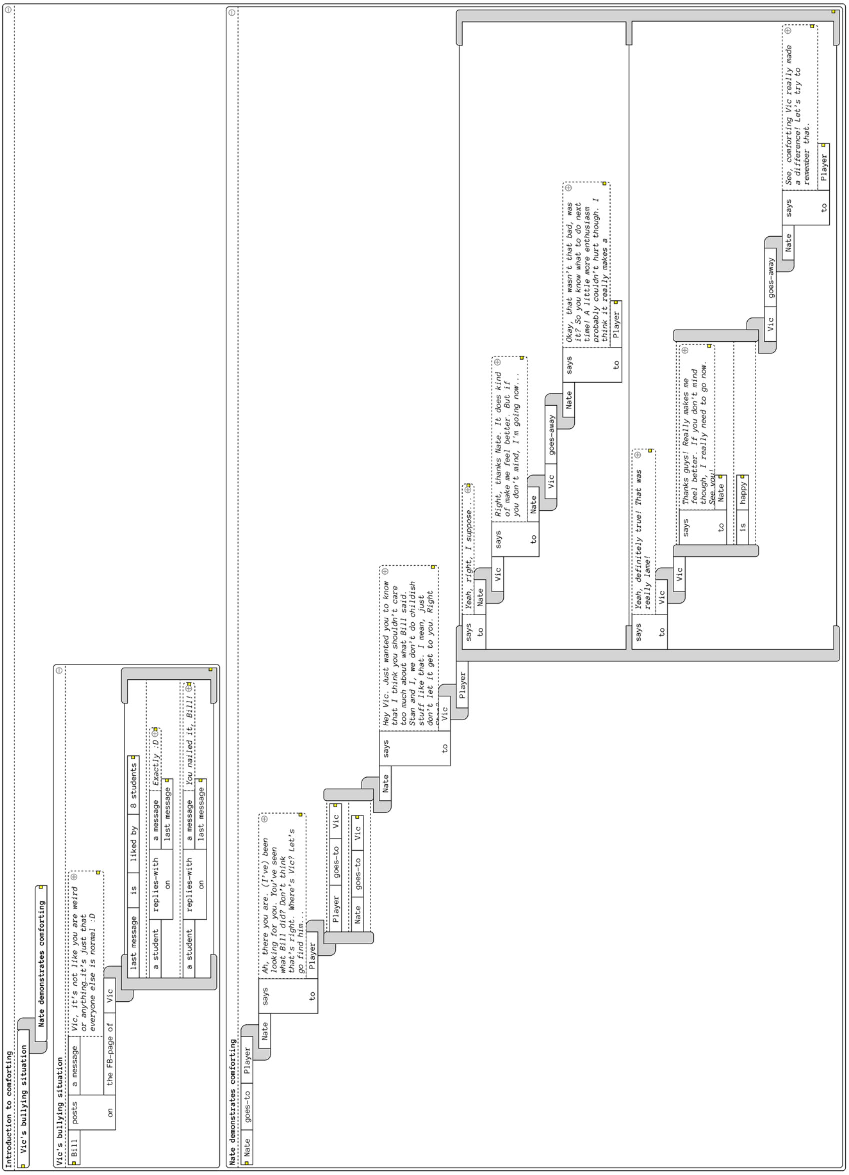

Fig. 4 Example scenario "introduction to comforting"

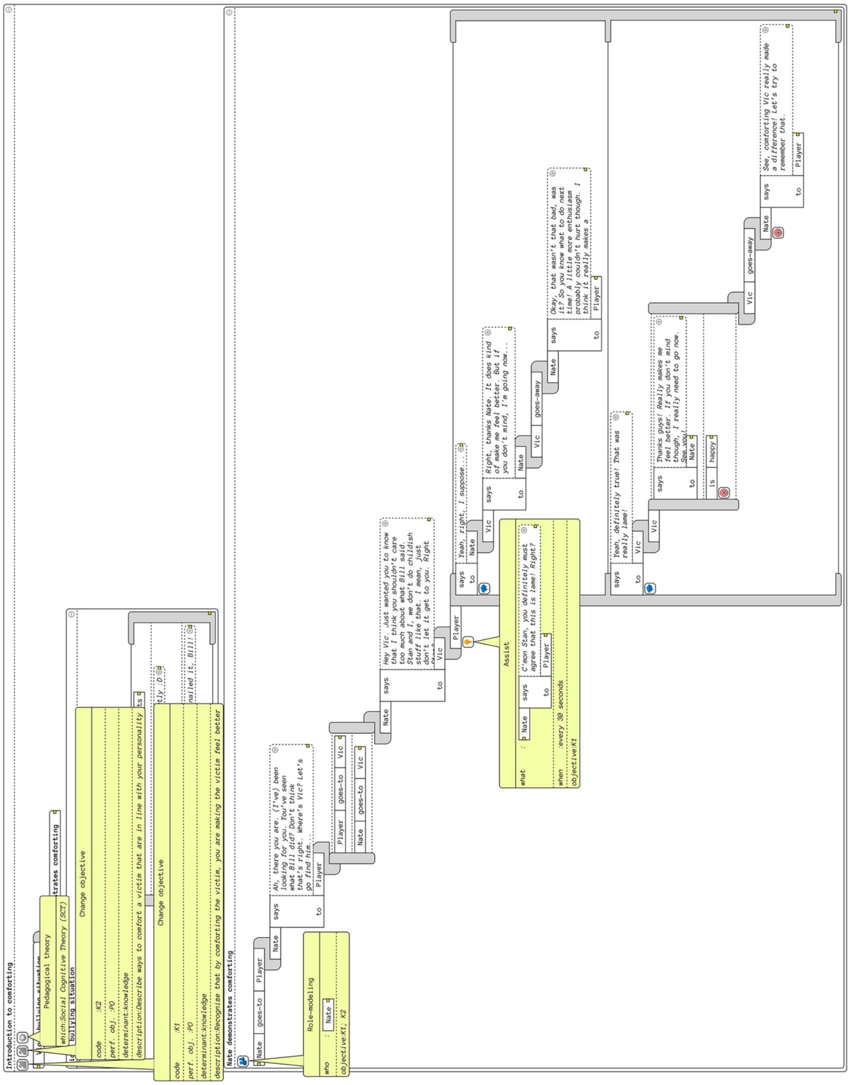

Fig. 5 A scenario (Fig. 4) annotated with change objective PAs for determinant "knowledge", a method PA for "role-modeling" and a theory PA for SCT

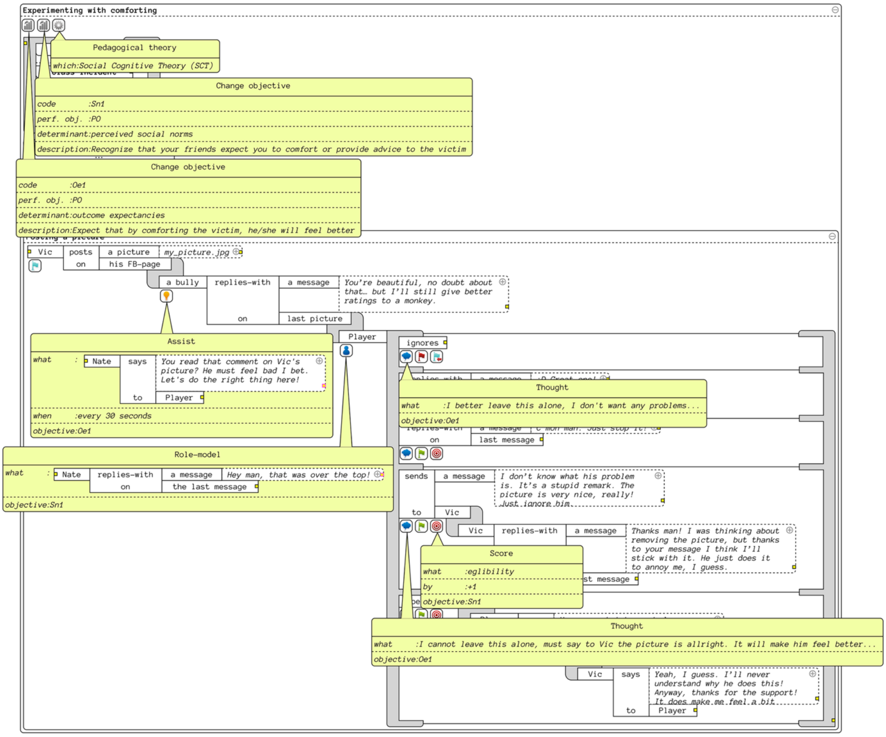

Fig. 6 A scenario with change objective PAs for determinants “outcome expectations” and “perceived social norms” and action PAs for “scoring”, “assistance”, “thought”, and “role-model”

objectives (see Fig. 6). The sub-scenarios should thus include intervention methods that affect these determinants with the aim of achieving the change objective. The link with the IMP intervention methods is explained in the next section.

Linking IMP intervention methods Similar as when using principles of pedagogical theories (see “Using SCT in a narrative” section), intervention methods identified with IMP can be embedded in a scenario in two ways: (1) as game mechanics that are complementary to the storyline, guiding the player in a certain way. or (2) as events expressed directly in the narrative.

Similar to the case of SCT, in order to express that an intervention method is realized through game mechanics (method type (1)) designers can use the *action PAs*. To create the link with the change or performance objective, the action PA includes an argument that denotes the targeted objective. Figure 6 shows the use of the score PA as a method for achieving the change objective “Sn1: Recognize that your friends expect you to comfort or provide advice to the victim.” (see Table 1). Similarly, the same figure uses two thought PAs to help achieving the change objective “Oe1: Expect that by comforting the victim, he/she will feel better.”

Again similar to the case of SCT, IMP intervention methods can also be embedded by expressing them as a part of the narrative (method type (2)). To specify this, the modeler can associate the *method PA* with the relevant part of the narrative. The annotation itself contains parameters to indicate the type of method used as well as the objectives it influences.

Conclusions and future work

In this paper we discuss how to explicitly link the storyline of a serious game with the underlying pedagogy. By combining pedagogical principles and narrative modeling, designers can improve the efficacy of serious games. To allow creating this link, a formal annotation system is used. Creating this link has two main advantages. First it allows incorporating the pedagogical design developed into the narrative in a rigorous way. Secondly, documenting the relationship between the storyline and the used pedagogical principles has not only the advantage of providing a detailed documentation, but might also allow for the formal verification that the serious game is respecting its pedagogical design. Furthermore, the integration of elements from the pedagogical design into the storyline through an elaborate but easy to understand annotation system facilitates the communication between technical and non-technical people. As such, ATTAC-L is a serious game design tool that can enable and stimulate multidisciplinary collaboration. ATTAC-L and its elaborate annotation system allow modelers to specify different aspects of a serious game like learning goals and story separately while still being linked. The clear separation between the narrative and other pedagogical and gaming aspects provide a better overview of the different elements of the serious game. As a consequence, designers with different expertise can concentrate on particular aspects of the game, while maintaining the relations with all others aspects of the game.

We explained the general principles of this annotation mechanism and how it can, in general, be used to specify the pedagogical aspects of a narrative-based serious game. Next, we detailed how to use the annotation system and its principles of extensibility for a particular well-suited pedagogical theory for serious games: Social Cognitive Theory (SCT). Finally, we showed how to explicitly link the outcome of a particular pedagogical design strategy, Intervention Mapping Protocol (IMP), to the storyline of a serious game. Similar approaches can be developed for other pedagogical theories and pedagogical design strategies.

ATTAC-L and its annotation system were used in the Friendly-ATTAC project (Friendly ATTAC 2012), which applied IMP to create a serious game to tackle the issue of cyber-bullying. Using ATTAC-L, the project team developed a serious game for youngsters based on intervention methods identified (including principles of SCT) with IMP. The output of ATTAC-L was used to generate parts of the code, which allowed speeding up the development process. As such, the approach seems to be adequate for a narrative-guided scenario where role-playing and scripted communication with NPCs is the primary focus. It remains to be investigated if the approach will also work for more complex scenarios.

Parts of the pedagogical annotations have already been considered during code generation. It is our goal to extend this set further and to extend code generation to cover all types of annotations. In future work we will also investigate how to formally verify that the serious game is respects its pedagogical design.

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