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To cite this version:

Pierre Laforcade, Viktoriia Vakhrina. A Domain-Specific Modeling approach for a simulation-driven validation of gamified learning environments Case study about teaching the mimicry of emotions to children with autism. [Research Report] LIUM. 2016. hal-01515230

HAL Id: hal-01515230

https://hal.science/hal-01515230v1

Submitted on 27 Apr 2017

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A Domain-Specific Modeling approach for a simulation-driven validation of gamified learning environments Case study about teaching the mimicry of emotions to children with autism

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Abstract. Game elements are rarely explicit when designing serious games or gamified learning activities. We think that the overall design, including instructional design aspects and gamification elements, should be validate by involved experts in the earlier stage of the general design & develop process. We tackle this challenge by proposing a Domain-specific Modeling orientation to our proposals: a metamodeling formalism to capture the gamified instructional design model, and a specific validation process involving domain experts. The validation includes a static verification, by using this formalism to model concrete learning sessions based on concrete informations from real situations described by experts, and a dynamic verification, by developing a simplified simulator for 'executing' the learning sessions scenarios with experts. This propositions are part of the EmoTED research project about a learning application, the mimicry of emotions, for children with ASD. It aims at reinforce face-to-face teaching sessions with therapists by training sessions at home with the supervision of the children's parents. This case-study will ground our proposals and their experimentations.

Keywords: Gamification Design, Domain Specific Modeling, Simulation, Instructional Design, Emotions, Autism

1 Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that often causes a significant developmental disability. It involves delay in the development of many basic skills including the ability to socialize and communicate. Individuals with autism have a limited range of interests, and struggle to bond emotionally with others. They also display repetitive behaviors and sensory processing disorders [7]. There is a considerable heterogeneity within those diagnosed with

ASD: it encompasses a range of developmental disabilities including autism, Asperger syndrome, and more general pervasive developmental disorders.

Children with ASD are known to have difficulties with the production and perception of emotional facial expressions. The improvement of facial recognition skills would most likely also lead to an improvement in social interaction and communication. Face processing abilities can be improved through effective training [13]. Technology has recently been playing a more active role in promoting facial recognition and generally helps individuals with ASD to understand emotions. Similarly, the use of gamification, serious games and off-the-shelf video games [9] in ASD interventions has become increasingly popular during the last decade [12]. They are generally seen as effective new methods in the treatment of ASD, especially for children. Computerized interventions for individuals with autism may be much more successful if motivation can be improved and learning can be personalized by leveraging principles from another emerging field of serious game design in educational research [41].

In this paper, we investigate the specific teaching step about the facial mimicry of basics emotions. Indeed The Emoted project aims to providing a facial-recognition technique allowing a children application to animate, in real-time, a mirroring avatar according to the children's face while performing the mimicry activity. In this multi-partners project our specific research issues concern the design of the children application. Based upon the assumption that some game components are more relevant to consider when designing a learning application for children with ASD, we realized a synthesis of various studies about this subject. We also studied with more further considerations existing serious games that proposes the mimicry of emotions for children with ASD. Despite the intrinsic efficiency of several research projects dealing with the same issues, we notice that existing works do not formalize the design of their game ingredients.They are not concerned about validating the relevance and effectiveness of these game elements as well as verifying their compliance with best practices about caring children with ASD.

We think that the overall design, including instructional design aspects and gamification elements, should be validate by involved experts in the earlier stage of the general design & develop process in order to reduce the re-engineering cost of the prototypes. We tackle this challenge by proposing a Domain-specific Modeling orientation to our proposals: a metamodeling formalism to capture the gamified instructional design model, and a specific validation process involving ASD experts. The validation will consist in verifying that the explicit domain model is relevant to support the learning of mimicking emotions. We propose two ways to verify it: (i) a static verification: by using this formalism to model concrete learning sessions based on concrete informations from real situations described by therapists; (ii) a dynamic verification: by developing a simplified simulator of the EmoTED application for 'executing' (i.e. handling) the learning sessions scenarios with experts that simulate the children's interactions.

The remainder of this paper is organized as follows: first, the research context, including the EmoTED project presentation, is given (Section 2). We then

synthesize several research studies about serious games for children with ASD, and present existing works about the mimicry of emotions these children (Section 3). We next define and comment our propositions (Section 4) before detailing our contributions (Section 5) and the experimentations conducted (Section 6). We finally conclude the paper in Section 7.

2 Research Context

2.1 Learning emotions for children with ASD

Six basic emotions are traditionally considered (happy, sad, angry, afraid, disgusted, and surprised) [10]. Complex emotions involve attributing a cognitive state as well as an emotion: they are considered more context and culture dependent [15] in comparison to the basic emotions that are universally recognized and expressed in the same way.

Children with ASD have difficulties recognizing emotions from facial expressions, vocal intonation and body language separately and in context [4]. In contrast to these difficulties, they generally have some enhanced abilities and skills in systemizing [3] that can be used to facilitate their empathy. In a similar way, various intervention programmes could be viewed as tapping into systematic skills and interests in order to teach empathy. Learning environments that offer predictable and repeating sequences are then relevant (DVDs, computer programs, mobile application, etc.).

Several instructional methods are generally applied for developing skills to children with ASD. Discrete Trial Training (DTT) [39] uses sequenced instructions and repeated opportunities with an error-less procedure. It is efficient, effective, and appropriate for teaching many skills that require a great deal of repetitions and are not intrinsically motivating. Over time, DTT procedures have also highlighted the importance of generalization. Naturalistic approaches of instruction seem to generalize more easily and effectively than others: incident teaching, pivotal response training, Natural Environment Training (NET) [24]. The more appropriate instructional methods for children with ASD have to be a combination of these applied behavior analytic procedures. The Applied Behavior Analysis program (ABA)[20] is one of them and can be considered as a general framework to also consider for teaching emotions. It consists in the following key-principles:

P1 Individual programme: students must have a programme that matches their strengths and needs.
P2 Task analysis: analyze skills or tasks that need to be taught, then break it down into small components or steps that it would take to complete the task.
P3 Discrete trial and prompting: teach each step separately.
P4 Reinforcement: plan to reinforce each step with something that is highly motivating for the student.
P5 Repetition and prompt fading: practise each step repeatedly until the student can carry out that component of the skill with no prompting.

P6 Skill development: build each step systematically until the whole task can be completed independently by the student.
P7 Data collection: frequently collect data in order to monitor the students acquisition of the skill and the effectiveness of the programme.
P8 Generalization: teach the student to complete the task in different settings, with different people and at different times.
P9 Developmental skill building: build skills developmentally in order to build a strong foundation that will serve to inspire self initiated life long learning.

Learning emotions is considered as a 10 step method from [20]. Among their various objectives (recognition of emotion, formulating its own's emotions, recognizing someone else' emotions, acting to induce one's specific emotion, etc.), one is about teaching children to physically express an appropriate facial emotion. It corresponds to the step 4 from [20] and considers verbal children who can already understand and formulate emotions from pictures. That is the challenge the EmoTED project aimed to tackle by encouraging the mimicry of facial emotions from an avatar representation.

2.2 The EmoTED Project

The project partners and objectives The EmoTED project aims to explore Virtual Reality technological solutions and techniques in order to help the mimicry of emotions for children with ASD. It involved two academic partners and one association about ASD. The first academic partner, ENSAM, has previously experienced designing and developing VR technologies based applications for individuals with disabilities. The LIUM, the secondary academic partner of which we are members, has been researching instructional design languages and authoring tools. The last partner, Cocci'Bleue, is a local and non governmental association that provides families with some educational and behavioral interventions accredited by the French National Authority for Health recommendations.

The project is supported by a programme funding organisation from local authorities for a period of 18 months. The project followed a global action-research methodology towards a main objective: to design and develop a facial-recognition prototype for helping children with ASD to learn about the mimicry of emotions. The facial-recognition technique aims at allowing the system to animate, in real-time, a mirroring avatar according to the child's face while performing the mimicry activity.

Because of the close involvement of the ASD experts in the project proposal, previous key-principles (cf. section 2.1) have been initially considered. The final system to develop is presented in the next section from an end-user perspective. It allows us to highlight the current issues to deal with.

Global uses and tools The EmoTED application is made up of two separated applications: the therapist application and the children physical game. This last one is a desktop PC software using an everyday webcam. It is intended to be

deployed and used in the child's home. The main usage is to support reinforcement activities which supplement the ones performed during therapists sessions. Indeed, concrete progress about teaching the mimicry of emotions is initiated and controlled by therapists. In order to reinforce learning between two therapy sessions the application will help in reinforcing, contextualizing and generalizing the learning process. It also reduces the therapy cost for parents and enhances their exchanges with the therapist. The application will be piloted by a learning scenario designed and deployed from the therapist application, thanks to a web connectivity, according to the child current progress and specific ASD profile. Performed activities will then be tracked in order to provide the therapist's application with some information to prepare the next face-to-face learning session.

The therapist application will have *a minima* these two uses: designing personalized learning scenarios and visualizing indicators from children's progress from the raw tracks collected by the EmoTED application. Although these functional needs will be dealt with within the project, the main focus lies on the children's application.

The general usage is then a reinforcement session with parental supervision. During the main mimicry activity the children will face a screen showing two similar avatars. One of them acts as the character to mimic for a dedicated emotion. The second avatar will be animated in real-time according to the child's face analysis. The instructions will guide the child to mimic the model avatar and compare it to what he is expressing.

The activities to perform have to be compliant with the child's ASD profile and his current learning progress. They have then to conform to a specific instructional design model. Also, a gamification of the mimicry activity has to be offered in order to keep the children motivated. We consider *gamification* in regard to the [9] definition: the use of game design elements in non-game contexts. Indeed, gamification works by making technology more engaging, by encouraging users to engage in desired behavior. It takes advantage of humans' psychological predisposition to engage in gaming.

2.3 Issues about gamification and instructional design

The project leader was in charge of all the Technology studies and propositions about face-to-face recognition in real-time with a simple webcam (translating basic emotions into facial action codings, comparing emotion-to-perform encoding with current facial coding, animating in real-time the mirroring avatar) whereas our participation within the EMoTED project consisted in formalizing functional and non-functional needs and requirements into specifications for guiding the design and development of the prototype. The project leader was also responsible for prototype development including the integration of our specifications.

In order to design reinforcement activities about teaching the mimicry of emotions we have to identify at first a specific model that the tool can reify and handle. This model has to mix several perspectives: 1/ instructional design in accordance to ASD care practices about how children with ASD best learn (from a global learning approach to fine-grained session parameters to set-up),

2/ gamification mechanisms relevant with ASD and customizable enough to be adapted to children's profile (preferences, reinforcers, current progress in mimicry skills, etc.).

These objectives are based upon the assumption that some game components are more relevant to consider when designing a learning application for children with ASD. These issues will be tackled in the state-of-the-art section.

2.4 Research method

Because of the multiple research challenges and integration needs within a general design-based methodology, we also decided to follow a design-based research for our specific contribution.

We concretely followed an iterative and incremental methodology into three iterations during a global period of six months. The first iteration focused on studying the research context and starting the state-of-the-art (ASD, gamification, existing serious games about learning emotions dedicated or not to children with ASD). Another focus was to draw a very first formalization of instructional design model. The second iteration focuses on the study of similar existent research projects focusing on the mimicry of emotions and a machine-interpretable specification of our instructional design language. Finally, the third iteration was centered on specification improvements, the development of a simulator for playing specific scenarios about the mimicry of emotions, and the validation of our propositions. Every iteration ended with all other partners meeting. Dedicated meetings with the ASD experts have been planned regularly during the entire project in order to discuss and validate our propositions. The research contributions and results will be detailed in the next sections. In the first instance we sketch the synthesis of the analysis of the current and existing situations.

3 State-of-the-art

We studied, separately, the various domains from our research context (characteristics of autism, emotions, serious game and gamification). We then looked at associations between two of those domains (e.g. children with ASD and emotions, serious game for autism, serious game for emotions). We finally combined all criteria mentioned previously: serious games for learning emotions to children with ASD. Because it is out of the scope of this research article to sketch all of them we propose to synthesize two important points into the next subsections.

Although our context consists more in gamifying a mimic activity than developing a serious game, the frontier between these two terms is not clear because gamification is much more about the design activity whereas a serious game can be the result of the design of the activity according to the fun it will procure to end-users. We then globally focused our attention on existing applications or research projects without distinction between serious games and gamified activities.

3.1 Serious games for children with ASD

Several articles have already reviewed serious games for individuals with ASD. Some are more generally dealing with "computer-based interventions" or "technology-based interventions" including serious game and gamification aspects like [5] investigating the use of Virtual Reality or [6] and [16] about interactive technologies for autism. More precisely relating to serious games [27][12][21][43][41] have reviewed articles focusing on serious games for ASD children in different aspects (technology classification, purposes of the serious game, characteristics of the intervention, effectiveness of interventions) and characteristics of the game developed. These reviews cover together case-studies from 2002 to 2014.

All reviews do not detail their numerous serious game case studies in terms of concrete game-designed elements. Gaming aspects are generally only sketches in terms of global interaction or general game elements from various levels of abstraction: for examples (from [43]) filling (shapes), game level up, multiplayer, collecting or beating objects, constructed shapes, puzzle pictures, and so on. [12] and [21] uses the "10 ingredients of great games" [32] (self-representation with avatars; three-dimensional environments; narrative context; feedback; reputations, ranks, and levels; marketplaces and economies; competition under rules that are explicit and enforced; teams; parallel communication systems that can be easily configured; time pressure) to score reviewed case studies. These 10 criteria recovers the 5 levels of game design elements proposed by [9]: they are at different levels of abstraction.

Nevertheless these reviews highlight some good practices, and sometimes propose suggestions or recommendations, for those interested in designing and developing serious games for people with ASD:

S1 to take into account dysfunctional sensory processing [43] in the activity design;
S2 to tap into children's interests when possible [27];
S3 to allow children to select their favorite characters at the beginning of the game from a range of faces that have been drawn as cartoon characters. They tend to play as a game character which is consistent with their real-life identity in terms of gender [43];
S4 to have customization tools so that parents and teachers can control visual & auditory feedback, to avoid negative or repetitive behaviors [43];
S5 to include, for in-person instructional supports, a modeling of correct behaviors, corrective feedback from teachers/therapists, and to provide additional in-person contexts for practicing learned skills [42];
S6 to propose different types of self-reflection prompts, tailored in developmentally sensitive ways that directly aid in learning and do not distract from game-play by being too easy, difficult, or abstract [28];
S7 to propose a game-method applying distinct rules which enable the player to understand and to win the game whilst playing. It is highly useful to indicate explicit and easy-to-understand rules, and try to only use one rule at a time. All this eliminates additional distraction and thus simplifies the use of the game-method for autistic children [12];

S8 to present a score panel of difficulty levels, so that it is easy for teachers and parents to recognize the childrens achievements [43];
S9 to put a strong emphasis on the visual design but take particular care to not overwhelm children with extra visual stimuli [12];
S10 to contextualize learning for easing the generalization [27];
S11 to include specific generalization activities for encouraging transfer of knowledge[41];
S12 to have a shorter duration for focused intervention practices and invest a longer period of time for comprehensive treatment [21];
S13 additional ingredients of games may also provide an enhancement through the chosen method, such as the narrative context [12] or marketplace or economies, and feedback [21];
S14 to use storylines: story-driven goals (especially when designed to be meaningful to the individual playing the game) can increase affective engagement and are thus critical for providing a rationale for driving game play [41];
S15 to focus on the inclusion of long-term goals that are tied to a narrative storyline. The specific storylines and narratives need to be directly integrated with the educational objectives to maximize learning potential [41];
S16 to promote communication between multiple individuals with ASD in cooperative games may provide unique and safe opportunities for them to practice communication and social skills within the game, as well as practice with working collaboratively towards achieving their goals [41];
S17 to pair with other activities that supplement the game-based instruction and encourage generalization of the material beyond the game [31].

The first six recommendations are about adapting the design to the children's profile whereas the other ones suggest general important design aspects.

Discussion about ASD-specific game designs Because of their general-purpose approach, current reviews do not tackle the suggestion of concrete game elements from the perspective of the gamification / serious game domain research. Nevertheless, it appears that not all game ingredients might be suitable for children with autism. For example, children who experience difficulties with collaborative play and social skills might not enjoy playing in teams. Other children can feel uncomfortable when wearing specific equipments. This is likely to be a reason some of the ingredients are rarely used. Therefore, the interventions should not be valued too much based on the used ingredients. The choices made in designing the interventions are rarely well-substantiated. [21] recommended to carry out more research into the demands of the children and designing the interventions in a more user-centered way.

The intervention training may need to be much more extensive. Serious game principles are designed to this point: they provide learning contexts that are more immersive and contextualized so that learning of difficult behaviors and skills can be scaffolded as motivation to learn them is intrinsically enhanced. As suggested by [41], interventions utilizing computer technology for individuals with autism

could be greatly improved upon and will likely produce better results by including more elements of serious game design. According to [42] and [41] blended computer and traditional in-person instruction model in autism interventions could be very efficient. The additional in-person activities may be helpful for providing opportunities for applying the learned knowledge in new settings, or for further reflecting on the learned material.

As mentioned by [41], the types of instructional supports should be chosen at a developmentally appropriate level for the individual learner, as individuals with lower meta-cognitive or language abilities may need differing types of instructional supports than individuals with higher meta-cognitive or language abilities. Applications like the one aimed by the EmoTED project have to be adapted to children's cognitive level. Adaptation can be considered at design-time by adapting the application, if targeted children share common cognitive characteristics according to the pedagogical objective, as well as at parametrization-time through the specification of dedicated learning scenarios by therapists. For individuals with higher language abilities, reflection activities to discuss the newly learned material with a teacher or peers could also be utilized as generalization activities [42]. Developmentally appropriate instructional support during therapy sessions may provide important scaffolding for increasing the generalization of emotions learning from the computer to in-person social and communicative behaviors.

All the recommendations are interesting but research has not yet been conducted to examine what types of instructional supports are most effective for improving learning for individuals with autism, and what personal characteristics (such as language abilities) predict individual differences in the benefits of these supports [41]. The use of well-designed serious game interventions, which is one of the EmoTED project objectives, for children with ASD may provide opportunities for cost-effective teaching tools that can be used at home, in classrooms, or other therapy settings to supplement traditional teaching methods.

The majority of computer-based interventions for individuals with autism using cognitive training or virtual reality paradigms do not include many of the key elements of serious game design. We agree with [41] who argues that future research should focus on key issues related to the design of the computer-based interventions. Nevertheless, some general game designs principles have been proposed by [1]. Their study was about understanding user needs from the perspectives of both parents of children with ASDs and the children themselves, with regard to learning facial expressions of emotions. Although the study was not focusing specifically on learning the mimicry of emotions, their four recommendations overtook the aforementioned discussions:

- to allow individual customization: avatars and interacting agents, feedback, rewards, combination of text / audio / video, visual elements of the game, context of the game environment (e.g., home, school, bus stop, or real environment etc.). It is necessary to effectively enable preferred feedback styles upon childrens characteristics and preferences.

- to incorporate context into the game: being able to understand how certain emotional responses result in a particular outcome should be a primary goal of an intervention tool. By providing context, children with ASDs may be better able to apply the skills learned within the game and generalize that knowledge to real-world situations.
- to enable adaptability: the game has to adapt to the behavior of each child. Being able to detect repetitive or negative behaviors, a loss of eye-contact, as well as to dynamically react from children verbal commands, etc. is a significant technical challenge.

3.2 Existent about learning mimic facial emotions for children with ASD

In this section we present and discuss existent serious games / gamified applications aiming at learning the mimicry of facial emotions. We do not address issues about the automatic facial expression recognition technology because it is not into the scope of our research contribution within the EmoTED project. We only focus our study upon the general game elements and interaction design from the authors point of view.

The CopyMe game. It incorporates a facial tracking and recognition system that categorizes six basic facial expressions made by the player according to three levels of difficulty (Figure 1). The authors aim to explore its effectiveness as an intervention tool for children with ASD [17]. The facial expressions are progressively introduced based on the game difficulties selected by the player. The game requires the player to observe a photo of a human face making one of the six basic facial expressions and to attempt to copy it whilst viewing his/her own face via the live camera feed shown on screen. The primary game input is obtained via the front device camera of the iPad. Touch input is used to navigate the menus and also to change an expression for another one. If the face is successfully mimicking the player receives a point and a new expression to mimic is presented.

The CopyMe game proposes distinct rules, different levels of difficulty for a mimic activity with a short duration. It does not cover other suggestions probably because of its background main intentions about the real-time facial analysis: the game is not aiming to be used with therapists or to rely on a specific progress according to the children's profiles.

LIFEisGAME prototype. It attempts to apply a serious game approach to teach children with ASD to recognise facial emotions using real-time automatic facial expression analysis and virtual character synthesis [2]. It has been developed as a PC version and an Ipad version. Depending on the version and the project progress reported in author's communications, several games modes about emotions have been designed: "Recon Mee-Free" (associate a thought to a

facial expression presented by the characters); "Recon Mee-Match" (match characters facial expressions to other models facial expressions); "Sketch Mee" (use the facial expressions drawn and make a dynamic video to watch the character's face change); "Memory Game" (pair up facial expressions of models) and "Build the Face" (the player draws facial expressions on the avatar s face according to a target expression presented in a card). The main character in the game is a boy with friendly features. Game feedback is both visual and auditory. The game focuses on positive feedback and mistakes made by the player are not valued.

One specific mode also aimed at exploiting the video input from the player obtained by the use of a typical webcam [30]. This "Become your avatar" mode has three levels. Level one is a free-play mode, where an avatar simply mimics the players facial expressions. In level two, the player attempts to achieve a target facial expression. Finally, level three is a follow-up mode, where the player must follow the expressions of an avatar. A "Live a story" mode was also originally intended, where the player is presented with a story and asked to perform the appropriate expressions to the situations depicted in the story. Facial features are located and tracked without using any markers on the face. They are then used for both, animating a virtual character, and recognizing the expressions of the player. Nevertheless it seems, by reading the complete project communications[1], that this research work has not reached a mature level to be integrated, through the dedicated game modes, into the final version of the game.

Similarly to the previous studied project, LIFEisGAME proposes distinct rules with a short duration for various activities about learning emotion. The levels of difficulty are partially tackled if we consider that a parent or therapist proposes the activities to the children according to their current needs and skills. The game also uses a strong visual design and deals with contextualization of learning within some of the proposed modes. Nevertheless the mimic activity seems to be missing in the final prototype.

ASC-inclusion project. This project aims to help children with ASD by allowing them to learn how emotions can be expressed and recognized when playing games in a virtual world [34]. The platform includes analysis of users gestures, facial, and vocal expressions using standard microphone and web-cam, training through games, text communication with peers, animation, video and audio clips. An internet-based game platform has been created. It assists children to improve their socio-emotional communication skills, attending to the recognition and expression of socio-emotional cues and to the understanding and practice of conversational skills [37]. The game is aimed for home use.

Concretely, the virtual environment is designed as a point&click narrative "Camp-Exploration": the player is a young researcher who joins an international research camp located in the jungle. With the help of animated characters they research human behavior and emotions. The main focus is the special hints and signs that can help in recognize other people's emotions, as expressed in their face, voice and body. The heart of the camp is the Research Center area.

[1] Retrieved here : http://www.portointeractivecenter.org/lifeisgame/?page_id=15

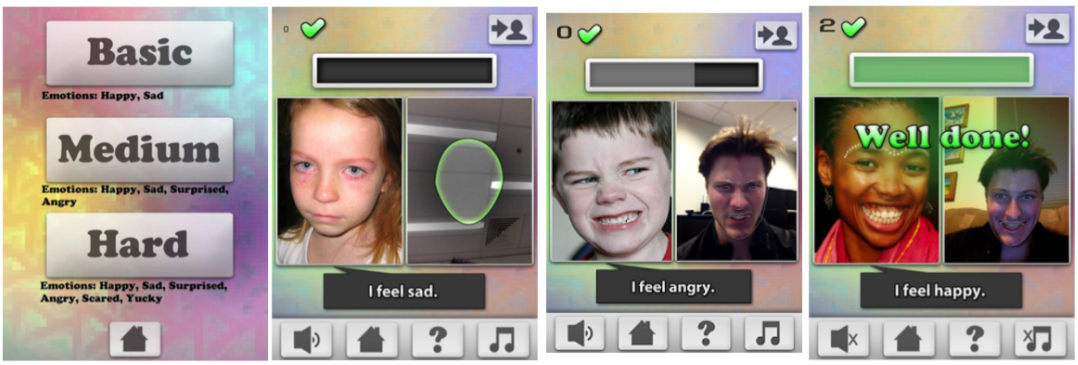

Fig. 1. Caption-screens of the CopyMe application [17] showing from left to right: the level selection screen with their related emotions, the general game screen when the face is not in view of the front camera, when the face is currently well-recognized, when the time-progress bar has been fully filled.

Fig. 2. Illustrations of the ASC-Inclusion virtual "camp-exploration" environment (from [35]). From left to right and top-bottom: the 'research center' location at the heart of the program from which the child can access his research tasks, the 'recreation zone' proposing some fun games to the child, the learning program manager application user interface, the Expression game with face, voice, and body gesture modalities.

It includes a learning programme manager application ("My Research Plan" screens) with access to 56 interactive lessons and some basic practice games. This content is "wrapped" with the following motivational elements and applications [35]: (i) a reward system; (ii) an avatar (personal virtual character that children can personalize by buying clothes and accessories; (iii) a virtual home ("The Camp-Home") that can also be customized with bought items; (iv) interactive collections (animated cards album); (v) out of camp fun locations where the child can roam to play fun games in exchange of coupon or bought tickets. The main principle is that children earn virtual coins for every "research session" (i.e. a lesson) and curricular practice game they complete, and have to pay with those coins for almost everything else (Figure 2). One game is the main activity in the expression sub-unit at the end of each of the learning units: the race board game. Each turn the child is asked to express an emotion in a chosen modality of their choice. If they expressed it well enough, the racing robot advances one step on the board. Whoever gets to the end point wins.

The ASC-inclusion environment is a strong visual and narrative environment with visual and sound parameterization settings, avatar choice, a strong storyline and several serious game elements around a monetary-system. It is based on user requirements collected from focus groups with parents of children with ASD, and experts. It does not provide contextualized activities or additional activities for generalized the learning skills. It has been experimented and evaluated with children aged 5 to 10 years. The face analyzer implements an automatic facial analysis system that is used to provide a visual feedback of the children's face into a dedicated window for therapists around the children. Clinical evaluations are considered as promising about the emotion learning but suggestions for improvements have to be tackled by future versions [36].

JeMiMe project. The JEMImE project [18], funded by the French Research Agency, aims at designing new emotion recognition algorithms in order to extend the features currently used in the JEStiMulE serious game (a multisensory serious game for training emotional comprehension and social cognition of individuals with ASD) [38]. The goal of the serious game developed in JEMImE project is to help children with ASD to learn to mimic facial and vocal emotions and to express the proper emotion depending on the context. The scientific issues tackled in this project are about the emotion characterization and the real-time and multimodal analysis. The serious game design is not approached from a scientific perspective from the dedicated research domain. According to the industrial partner[2] in charge of this design the future application will complete the JEStiMulE game with a new Human-Computer interaction: we can then consider the mimicry of an emotion as an interactive activity embedded when the avatar directed by the child meets other virtual agents in the 3d environment (see Figure 3[3]).

[2] Website: http://www.idees-3com.com/en
[3] Retrieved from http://www.jacquesdedeken.com/#!jemime/cndy

Fig. 3. Illustration of a prototype for the facial mimick of the JeMiMe application.

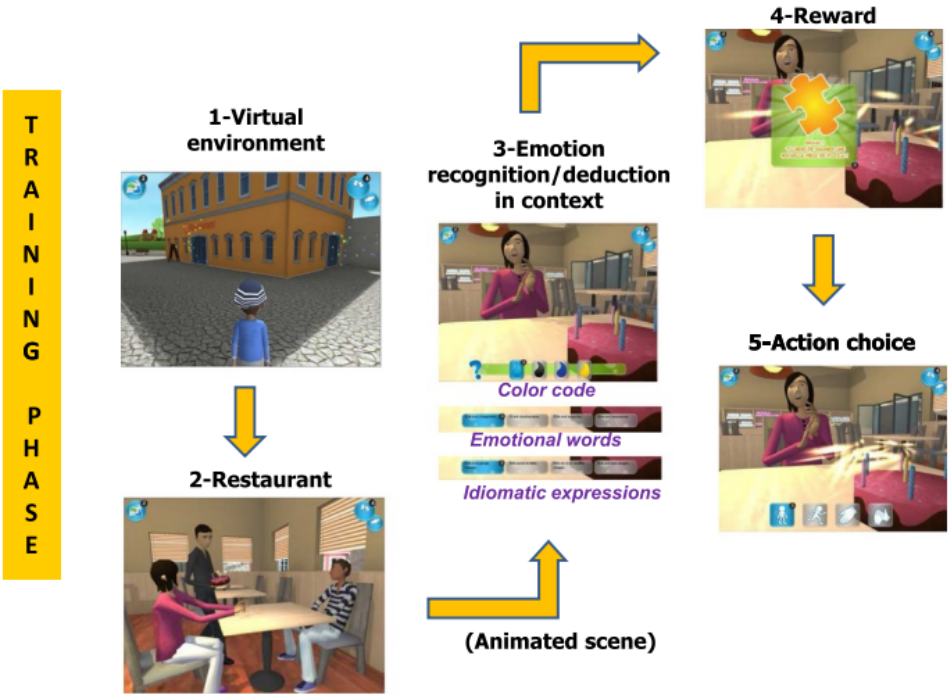

Fig. 4. Illustration of the training phase of the JEStiMulE application (from [38]).

We then decided to sketch the current JEStiMulE prototype: it is an individual interactive and virtual reality game with a multi-sensory environment (visual, tactile and auditory stimulations), played with a gamepad. It aims to hone emotion recognition skills, including facial expressions, emotional gestures,

and social situations. Participants were first trained to recognize different emotional faces and gestures from static and animated avatars (see [38] for further details about this learning phase). The training phase included three modules (embedding 30 scenarios) in which the participants could apply the knowledge acquired during the learning phase of the game. Before starting, the participant had to choose and personalize his/her own avatar. The training took place in a virtual city, where the participants avatar could move freely in different areas (square, garden, restaurant, etc.). The participant is free to interact or not with the other avatars in the game. When the participants avatar approached another avatar, an active social scene is automatically initiated (Figure 4). Children had then to identify the emotion expressed in the scene (either by recognition or by deduction). Only one response modality (a color code, emotional words or idiomatic expressions) is available, in accordance with each participants profile. A correct response delivers a piece of the puzzle (the participants goal is to complete all 30 pieces). Once the puzzle is completed, children can go to the theatre, sit down, watch their favorite scene and imitate the presented emotion. All scenes with incorrect responses appeared randomly in successive trials.

If we consider the JEStiMulE and JEMImE projects conjointly, they cover most of the recommendations about customizations towards children's profile and overall design aspects for children with ASD. In addition to the suggestions already covered by all previous serious games, this project proposes a very strong narrative immersion within a children-oriented realistic 3D-environment that is very relevant for contextualizing the emotions learning as well as generalizing them to real situations. Many customizations (the avatar children are controlling, the prompts and feedbacks to interact with the others avatars met when playing, etc.) are provided. But if we consider more precisely the mimicry activity, this one is considered here as another interacting way, not really as the focus of learning. Also, children are free about the way they play the game: the underlying instructional method is much more about *incident teaching* and (virtual) *Natural Environment Training*.

4 Proposals for the EmoTED project

4.1 Findings and scientific position about instructional design

Current tools and research prototypes dealing with the mimicry of emotions cover partially the design recommendations listed in Section 3.1. Nevertheless, none of them directly addresses all the usages aimed by the EmoTED project. They deal with the mimicry of emotion as a game, a way for interacting purposes, but not as a targeted skill to learn about. Although they explicitly state some general design models or gamification elements they do not formalize the study, design and validation of the relevance and effectiveness of the used game ingredients. No models or dedicated design processes are discussed because there are no research expertise among the researchers involved within theses projects to follow such a design perspective. The underlying instructional models are also not

explicit. Authors do not relate their propositions to key-principles about teaching/learning for people with ASD. However, they generally state the involvement of ASD experts (parents, therapists, medical researchers, etc.) to justify some design choices, sometimes mentioning experts' recommendations. Similarly, validation results are more focused about clinical experiments to evaluate the overall skills about learning emotions (recognizing, expressing, etc.) with no specific focus on the mimicry ability and facial expressiveness of emotions. Iterative design and development processes are followed, wherein user requirements and experts' recommendations are refined and further analyzed, tailoring the needs of the target audience, following usability tests results based on intermediate prototypes.

We think that the overall design, including instructional design aspects and gamification elements, should be validate by involved experts in the earlier stage of the general design & develop process in order to reduce the re-engineering cost of the prototypes. We tackle this challenge within the perimeter of the EmoTED case-study.

4.2 An instructional design perspective: proposition and issues

Our rationale is grounded on an instructional design perspective: the EmoTED application is considered, at first, as a black-box delivery system dealing with the learning of facial expressions in order to express specific emotions. The performance of a gamified learning session can be based upon a specific pedagogical scenario involving three informational facets:

- elements about the children's profile;
- elements about the learning session setting-up (including informations about the current progress);
- elements about the configuration of the raw datum to collect (in order to build pedagogical indicators that make sense for the therapist).

By default all interactions will be tracked upon the delivery system while performing the learning sessions: the third facet will be considerably reduced. The two other facets are concretely the most important. The challenge consists in identifying, formalizing and validating these facets in order to crystallize this specific *domain* model. The formalization should explicit the gamification ingredients that will be chosen, as well as the key-principles related to the underlying instructional models for an ASD audience.

The validation will consist in verify that this formalism is relevant to support the learning of mimicking emotions. We propose two ways to verify it: (i) a static verification: by using this formalism to model concrete learning sessions based on concrete informations from real situations described by therapists; (ii) a dynamic verification: by developing a simplified simulator of the EmoTED application for 'executing' (i.e. handling) the learning sessions scenarios with experts that simulate the children's interactions.

We identified several issues to tackle this challenge stated here as research questions: (Q1) how to formalize this very specific domain model? (Q2) How to

be able to formally specify some learning sessions scenarios in conformance with the domain model ?(i.e. how to guaranty a machine-readable format to handle the scenarios?) (Q3) How to simulate the execution of these scenarios to validate the game elements as well as the instructional elements for teaching/learning with children with ASD?

4.3 Research Methodology following a Model Driven Engineering approach

The Model-Driven Engineering (MDE) research domain promotes an active use of 'executable' models throughout the software development process, leading to an automated generation of the final application. These models are sometimes defined using general-purpose modeling languages like the UML, but for restricted well-known domains, it is also frequent to use some Domain-Specific Modeling Languages (DSMLs) tailored to the application domain and objectives of the project [19]. In current MDE practice, DSMLs are built by the language designer using a meta-metamodel expressed with a general-purpose meta-modeling language, like the MOF [29]. A DSML is then defined as a set of all possible models that are conformant with the modeling language's abstract syntax (the metamodel), represented by one or more concrete syntaxes (the different notations) and that satisfy a given semantics [33]. Finally, a model conforms with a metamodel meaning that the model should satisfy the rules defined at the level of its metamodel. The abstract syntax (metamodel) defines all the names of the identified concepts, and their respective relations. It also includes the "structural semantics" (or static semantics) that is mainly focused on setting binding rules among its elements.

The proposition of the MDE research framework to tackle the EmoTED challenges is the result of our cross-disciplinary researches and experiences about MDE approaches for *Technology-Enhanced Learning* applications [23][22][11]. Within the EmoTED project scope we propose to exploit the meta-modeling activity for answering previous Q1 to Q3 research questions. We consider the learning session scenario as a model of the concrete learning session parameters that a therapist would like to set-up in order to customize the EmoTED final application for a personalized learning session. We propose to identify and capture this very specific domain model into a metamodel (answer to Q1). A metamodel specifies the abstract syntax and static semantics of a modeling langauge. We do not aim at providing therapists with a complete modeling language (concrete syntaxes are missing) for designing such learning session scenarios.

MDE approaches are conducted by several technologies and usually supported by complex tools. Most of them provide a collection of features to help users to define DSMLs, with specific editors, model validation, model transformation, etc. The Eclipse Modeling Project[4] is one of them. It focuses on the evolution and promotion of model-based development technologies within the Eclipse community by providing a unified set of modeling frameworks, tooling,

[4] Eclipse Modeling, http://eclipse.org/modeling/

and standards implementations. EMF (Eclipse Modeling Framework) [40] is the core modeling framework and code generation facility for building tools and applications based on models defined in the Ecore meta-metamodel (the MOF equivalent within this metamodeling ecosystem). The general Eclipse Modeling Project is one of the most popular technology: its frameworks are relatively easy to use and maintain, and they have an open and strong community support. We experienced several of these frameworks within our past research works (EMF, GMF, SIRIUS, Epsilon, ATL). We propose to concretely rely our EmoTED propositions on the EMF code modeling framework.

Our learning session metamodel will then be specified thanks to the EMF framework (answer Q1). Hence, modeling a learning session scenario in conformance to our metamodel is straightforward with EMF: it produces, among other features, a set of Java classes for the model and a basic editor. Models can then be specified using this basic tree-based editor (answer to Q2). Concretely the scenario is serialized by the editor in an XMI format. We finally propose to develop a console based Java application to simulate the performing of the learning session specified int the scenario (answer Q3). This simulator will load the scenario at first and will produce during the simulation an other model, also in conformance to our initial metamodel, that embeds the generated tracks about the progress/interactions during the simulation.

5 Contributions

First of all we on purpose propose to present the global design elements that have been iteratively identified to be included in the gamification of the mimicry application for children with ASD. We then present and discuss the original iterative and incremental process we followed involving ASD experts in order to identify and validate these design elements. This process could be considered as a first proposition reproducible in other contexts in accordance with our instructional design perspective upon a *Domain-Specific Modeling* approach. Next sub-sections will present and discuss our other contributions in regard to the process steps we propose.

5.1 Instructional model and gamification elements

The following elements are annotated in reference to the key-principles P1 to P9 (instruction design principles for children with ASD from Section 2.1), and suggestions S1 to S17 (recommendations for designing serious games for children with ASD).

Inside the mimicry activity First of all we consider that the mimicry of an emotion corresponds to several facial action units [14] (muscles with intensity) and that have to be globally reached and maintained. Every children will have some personalized and evolving thresholds for each facial unit related to a specific emotion. Our underlying instructional model follows some of the Discrete

Trial Instruction guidelines. DTI uses error-less teaching procedures to prevent repeated errors but it is difficult in the context of facial mimicry to force the good realization of the mimicry. We decide to split the mimicry activity into two steps. First, the child has to perfectly mimic the concerned emotion showed by the animated avatar according to his/her thresholds and under a time-limit constraint. In case of failure (time-out), a second step starts. The animated avatar shows a freeze mirrored representation of the children's best facial mimicry from step 1 (calculated with a dedicated 'distance' metric). The animated avatar then prompts the children to try overstepping current mimicry levels closer to the thresholds. Because in-activity details are more focusing on animations and detection features out of our scope we do not precise more details. If the children still do not succeed in step 2 (another time-out), then a final animation will be performed by the animated avatar to show again, slowly, how to perform the mimicry of the considered emotion from a neutral facial position.

Outside the mimicry activity The game is structured as an inter-connection of screens representing some meaningful scenes of children's life (school, home, zoo, inner city, farm, etc.). A global screen (Figure 5) acts a central hub showing the various scenes, their linear connections and their current status (locked, available, achieved) with dedicated visual feedbacks (achieved scenes are in color, current scene is highlighted, locked scenes are in gray levels). Each scene is composed of dedicated characters and objects in gray levels mode. The selectable elements are highlighted. Their number is dependent to a current token economy. They acts as a trigger event to launch a reinforcement activity. According to the success or not of the emotion mimiryc the related scene elements remain highlighted (i.e. selectable) or switch to color mode. Before starting the mimicking activity, a first part of a non-interaction animation appears in relation with the current scene. This first part of contextualization aims to introduce a situation wherein the future emotion to mimic is considered as relevant. A second animation part will be played after the reinforcement activity, in both success or failure cases. A character will express the related emotion according to the context from the first part. For example, the first part could show a child hit by a football while playing whereas the second part will show his reaction of sadness because of the pain. The selected character or object that triggered this animation do not always appear into the current scene because of the large number of animation it would imply (the animation is already related to the random emotion according to the children's learning profile and the current scene). When all random animations for a given scene and a given emotion have been played, they are all considered available again. When a new scene is unlocked, several changes can occur: modifications of avatars' representations, token economy for the next scene unlock, number of selectable elements. The game ends when all scenes have been achieved. After a dedicated ending animation, the game is reset with "new game +" parameters (starting scene, inter-scenes relations, selectable elements and token economy per scene, etc.) in order to level

up the difficulty. These changes would have been specified by therapists when setting-up the scenario.

Transversal aspects We decided to propose different avatar representations but this choice is made by the therapist according to the children's preference in terms of gender (male, female) and in terms of rendering details (cartoon face versus more realistic human face). Indeed, ASD experts stated that this representation could have an incidence on the understanding of the avatar to observe and mimic. The cartoon representation will be preferably choose for new emotions to acquire or to contextualize while the realistic one will be used for learning sessions involving acquired emotions to generalize. Obviously both avatars (the children's mirroring one and the animated one) will always use the same representation.

As soon as there are at least two emotions related to the learning session, the therapist can set the ratio between *reinforced emotions / emotions to reinforce* with a default value of 80% according to the ABA approach rules. Therapists consider that an emotion mimicry is reinforced if children succeed, during the step one, in three consecutive tries for this related emotion (i.e. other emotions mimicry can occur between these tries). We also propose different intra-activity guidance types: visual animations, for the animated avatar, audio or textual prompts and indications. Concrete guidance from these modes can be selected and cumulated by the therapist according to some children-related conveniences.

A reinforcement activity will be available after each mimicry success (during both two steps). This reinforcer is a setting related to the children's profile. It could be an animated activity (balloons pop, pictures collage board...), a sound to play (like animal sounds), a picture to unlock in a specific album, etc. All reinforcers will have fine-grained parameters in order to be customized to children's preferences. Apart the mimicry activity screens, a token economy will be visible on the game screens. It will visually show the contract about the unlock of a new game scene after a fixed number of tokens. These tokens are related to the current scene objects upon which children can launch mimicry activities. Visually the token can look like an iconic picture of the related scene object or can be a star, coin, etc. By default, the activity success (steps 1 or 2) will unlock one token. A dedicated animation will propose a visual feedback of this unlocking. This is important to help the children understanding the game rules. We propose then two levels of reinforcers: a strong one that is triggered when a visual contract is achieved, and a weak one after each mimicry activity success.

From all these aspects, three game modes have been identified:

- learning sessions: focus on the maintain of acquired emotions and the learning of new ones; a cartoon representation is used for avatars; no contextualization animations surround the mimicry activity;
- contextualization sessions: animations around the mimicry activity; all emotions have already been acquired but still have to be trained and maintained;

– generalization: idem as previous sessions but with a realistic avatar's representation.

Fig. 5. Design mockups of the children's application; main screen showing the scenes (left); focus on a scene (right).

Several "times" are considered when using the Emoted Applications. The use of the therapists' application is restricted to their offices while the concrete serious game about the mimicry of emotions is restricted to children's usage and homes. Therapy sessions end with the setting-up of a personalized scenario that will drive the mimicking game until next session with the therapist. Learning scenarios act as machine-readable configuration files that specify all the setting-up parameters required in order to customize the game to the children's profile and current progress. We do not tackle for now the computerized perspective about the access and delivery of such scenarios as well as the feedbacks of children's raw datum and tracks. During the home period, children can perform one to several game sessions, each one participating in the game performance (unlocking of game scenes and objects). Therapists asked to not forbid the use of the mimicking game when the end is reached. We then propose a kind of new "game+", a new run of the entire game but with adjustments for the parameters. Indeed, each game iteration has to propose some new challenges, i.e. a progression of the difficulty level according to current mimics of emotions. Therapists choose to mainly adjust the token economy: more tokens (i.e. more successes through the selection of scene objects) are required to validate the scene and unlock the next one. Similarly, each scene has to propose an equivalent number of scene objects according to this new contract.

The mimicry application will collect all children's interactions, choices and game informations during all game sessions. These tracks will be used to propose high-level indicators for therapists.

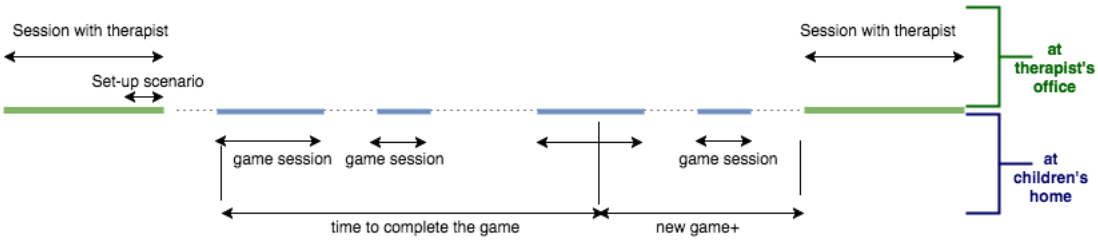

Fig. 6. Different times using the EmoTED applications (upper annotations are related to the therapists' app while lowers ones are for children' uses).

5.2 Iterative and incremental process about (meta-)modeling and verification

The previous general instructional model characteristics and gamification elements have been defined at first on the base of an initial interview and brainstorming with ASD experts involved within the EmoTED project. Then, they have been refined through several iterations according to the following process (Figure 7). This process only concerns the children's application (no focus on the therapists' app).

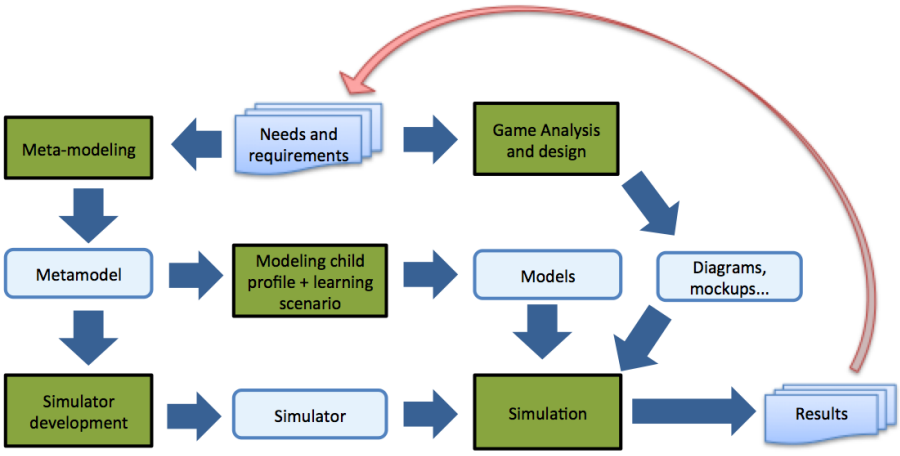

Fig. 7. The metamodeling-based process from needs to simulations in order to verify and validate the game designs mechanisms in accordance with the ASD context.

The green rectangles corresponds to the activities we performed whereas the blue rounded rectangles represents input/output artifacts. At first, requirements and users needs are translated into mockups of HMI screens (visual perspective of underlying game design mechanisms) and UML activity diagrams (to capture

the dynamic perspective). They are also abstracted and formalized through the meta-modeling activity. It results in producing a metamodel capturing all instructional and gamification elements as children's profile and learning session parameters. This metamodel is concretely specified with the EMF framework. Then it serves as a basis for generating the Java code related to the model part. This code is completed by Java code specific for simulating the learning activities. The Java code for the EMF-based editor is also generated from the metamodel. The editor is then used to specify a conforming model, the learning session scenario, including the specification of the children's profile on one hand, and the learning session parameters on the other hand. Finally the simulator and the input scenario are executed. The ASD experts use the console-based application to simulate the children's interactions, choices, successes or failures during the mimicry activities. We also reuse the mockups in order to guide them in visualize the different game screens wherein the interactions should take place. Direct observations from ASD experts as well as tracks analysis are used by both experts and engineers to refine the initial needs.

5.3 EmoTED Metamodel

One first challenge was about the metamodelling activity: formalizing the characteristics informally described in Section 5.1 into a formal metamodel (i.e. machine-readable format) according to the EMF tooling and best-practices. Like other models, metamodels are quite subjective. We discuss the following metamodel we propose (Figure 8) in order to highlight our intentions rather than our metamodeling choices. Concretely, the metamodel is an ecore model that is persisting into an XML file. The default EMF tree-based representation is not enough readable so we propose a diagram-oriented representation generated by a GMF[5] feature.

First, the root element is the game session and its type between learning/contextualization/generalization. Then, we consider every game sessions as composed of 4 sub-components:

- Game Components: it contains the declaration of the components that therapists can refer when specifying a learning scenario. This elements describe the features included into the game: available emotions, available stages with all their selectable elements, scenes (i.e. the contextualization animations) per stage and with their relation to an emotion, the available reinforcers and avatar representations.
- Child's profile: it gathers all children's related parameters that therapists have to set-up to customize the learning session to a specific child: emotions acquired, emotions to maintain/train, learning ratio about the random choice of emotions, the avatar representation (in accordance to the GameSession type), the weak & strong reinforcers.

[5] *Graphical Modeling Framework*: an Ecore-based framework that allows the specification of graphical editors on top of Ecore models.

- Scenario: this part concretely define the sequence of stage. It can be defined in accordance with the children's preferences. Therapists can also change the stages order to keep the engagement for children with ASD that will not be affected by changing such routines. The *OrderedStage* is then related to one existing stage and allow the definition of a token economy for this very stage. This modeling approach allows us to separate global informations about stages (their selectable elements) to sessions-specific informations about them (subset of selectable elements that will be used for the stage according to the current token economy).
- Raw Datum: informations during the runtime will be collected and persisted into this model section. Therapists do not define them: the *RawDatum* is empty when the corresponding learning scenario (i.e. a model in conformance with this metamodel) is deployed to the children's application.

This metamodel distinguishes the composition of elements (black diamonds on the parent side in Figure 8) from references to existing elements (relations without diamond). Composed elements are nested within their parent container whereas referenced elements have to be part of another metamodeling classifier. This distinction is important to understand how future models will be built. Another implicit subtlety is about the ordering of composed/related elements. They are natively ordered according to their creation order. Nevertheless this order has generally no importance for the future machine-interpretation of the produced models, except for the relations *orderStages*, between a *Scenario* and the *OrderedStage*s, and *concernelElements*, between a *TokenEconomy* and *SelectableElement*s. The first ordering will be used by the simulator to adapt the sequence of stages whereas the second ordering will be used, according to the current number of selectable elements (i.e. *initial* value + (Game number -1) * *increment*), to add the right elements to the stage.

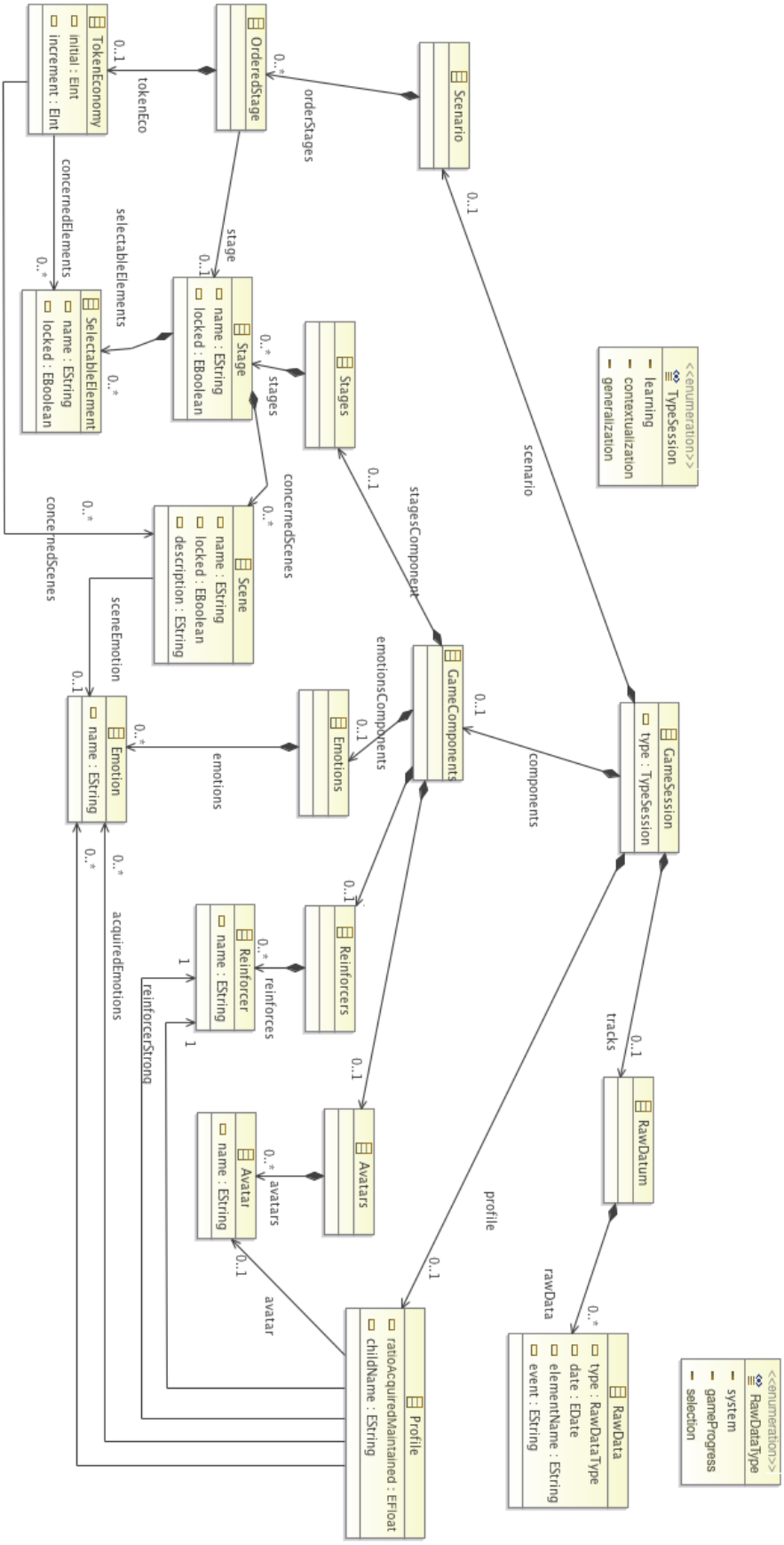

Fig. 8. The final metamodel (abstract syntax) allowing the formal specification of learning scenarios about the mimicry learning.

5.4 Modeling session examples

The EMF framework includes tools and runtime support to produce a set of Java classes for the model, along with a set of adapter classes that enable viewing and command-based editing of the model, and a basic editor. All these Java code is generated from the domain Ecore model (the metamodel). We use this basic tree-based editor for specifying models in conformance with our previous metamodel. Because of the distinction in the metamodel of the game components (that are available for all learning sessions), the children's profile (specific to one child), and the scenario (that can be reused for different sessions of a child), we exactly specified fictive learning sessions as three modelling steps:

1. Modelling the game components: as illustrated into Figure 9 we started by specifying the different stages, emotions, representations for avatars, reinforcers activities; we then detailed for every stage their selectable elements and scenes. The *Properties* view of the EMF-based editor shows the properties and relations for the selected elements from the tree-view (for example, the Figure 9 shows the details of a scene).
2. Modelling the children's profile: Figure 10 (left) shows an example for a child named "Oliver" who already has acquired the mimicry of emotions *Joy* and *Sadness*. The *fear* emotion is in progress to be acquired with a 80% ratio and a cartoon-like avatar's representation of a boy. A balloon activity is defined as strong reinforcer whereas a sticker activity will be used as weak reinforcer.
3. Modelling the session scenario: the sequencing of stages, the choice of selectable elements, available scenes and token economy for each stage is finally specified (Figure 10 - right). Each token economy also precises the number of selectable elements to display in the stage for the first run (*initial* value) as well as the increment for the new game+ sessions. Once this number will be calculated at runtime for a specific game session and stage, the selectable elements will be picked up as a subset from the ordered *Concerned Elements* property of the related stage. This property and the *Concerned Scenes* one also allow therapists to set aside elements and scenes that can interfer with the children's behaviour.

The second and third steps are concerning a same child: we then specify both profile and scenario within a same file, separately from the file embedding the Game components model. The children-specific file is using the other file thanks to a cross-model references feature provided by the EMF modelling framework. EMF instances (like our model split into two files) are automatically serialized by the EMF editor in an XMI format.

5.5 Simulator Development

The simulator has been developed by reusing the Java model code generated by the EMF framework. We also used a read/write save feature from the EMF generated Java code that allows us to load our previous models into the simulator at start and to save the model, when the simulator is quitted, in order to add and

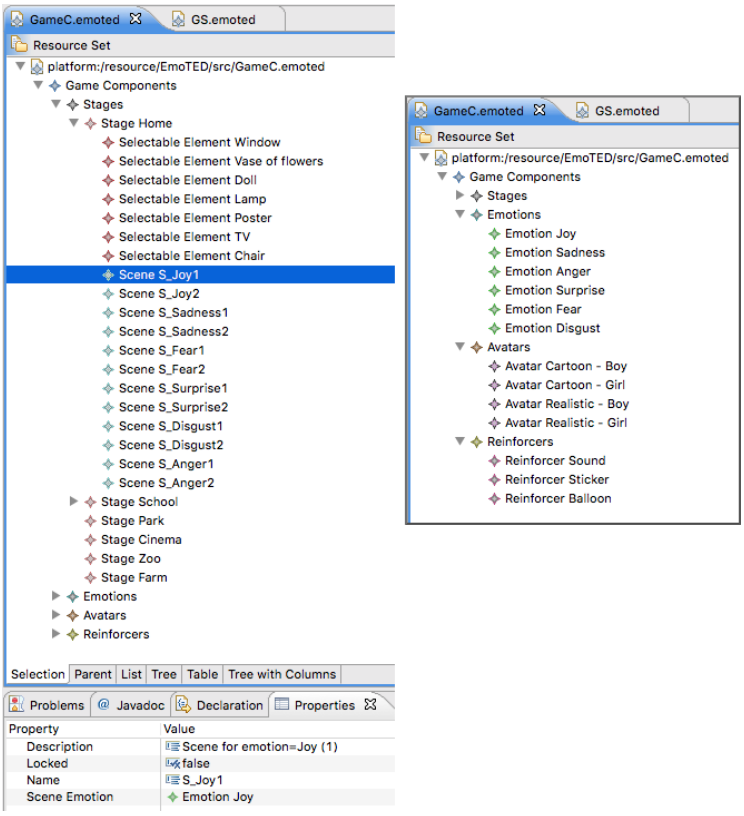

Fig. 9. Modelling the game components (stages, scenes, selectable elements...) that will be available for all learning sessions and children.

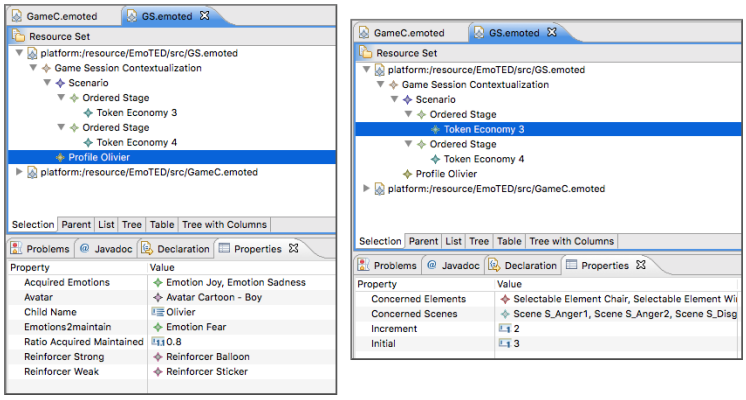

Fig. 10. Modelling the children's profile and game scenario.

persist the raw datum about the runtime informations. The simulator code is mainly embed into one Java class. Methods are mapped to the dynamic activities we designed and formalized into UML activity diagrams during the analysis phase involving the TSA experts.

The simulator is developed as a very basic text-based application. It starts with the loading of the session model. The different screens and interactions we identified with experts are simulated as text-information, for the description of all screens (main screen, stage and mimicry screens, etc.) as well as for indicating the various prompts, guidances, reinforcements, etc. that should appear in these screens. The children's interactions are simulated here through text-oriented choices. The following verbatim excerpt shows an example of simulator execution flow at runtime.

```
******* INIT *********
Track manager creation
Scenario file loading...OK
******* Child Profile *******
This scenario is for: Olivier
Emotions to maintain: Fear
Acquired Emotions: Joy Sadness
Ratio acquired / to maintain emotions: 80/20
******* Information about the learning session *******
Session type : Contextualization
Start a new game?
1 - yes
2 - no
Your choice?
1
***** INIT NEW GAME *****
Stages and selectable elements OK
***** NEW SESSION *****
Homescreen displaying:
- Home
- School (NOT still available)
Your choice?
1 - stage Home
2 - quit the game session
Your choice?
1
The stage 'Home' displays the following selectable elements:
- Chair (available)
- Window (available)
- Lamp (available)
Your action?
1 - Chair
2 - Window
3 - Lamp
4 - back to homescreen?
Your choice?
```

```
2
**** Action ****
Emotion Fear randomly selected
Ratio actuel : 0/100
Random appropriated scene selected: scene 1 for Fear emotion
The first part of the scene is played
Prompts for the mimicry activity
(SIMULATION) Step 1 Fear :
Fear emotion mimicry success?
1 - yes
2 - no
Your choice?
2
The mimicry activity is not correct
New prompt for the mimicy activity second step
Specific guidance based on a 'picture' of the better mimicry performed in step 1
(SIMULATION) Step 2 Fear :
Fear emotion mimicry success?
1 - yes
2 - no
Your choice?
1
Success of the mimicry activity step 2
The second part of the scene is played
The weak reinforcer Balloon is launched
...
```

The simulator also takes into account the various times (cf. Figure 6). It is possible to simulate different games sessions, the end of the game, etc. It is particularly required to test the token economies beyond different games. It also allows to test the different steps for the mimicry activity, the display of reinforcers at the appropriate time. All information, choices, system actions are tracked: specific raw datum are generated during runtime and are persisted within an XMI model file when exiting the simulation. They are then available for helping the post-simulation analysis.

6 Experimentation and ongoing works

Design suggestions from Sections 3.1 and 3.1 have been used during our brainstorming with ASD experts to guide and animate the discussions that finally end up with the domain model presented and formalized in the previous section. Most of these recommendations have been finally included. We precise in the next subsection the context of our experimental exchanges with the ASD experts. Next subsection sketches the VR-partner results and mention the ongoing works to tackle in addition to the current EmoTED project scope.

6.1 Case-studies Experimentations with ASD experts

The experimentation objective is to test and validate the game designs mechanics and dynamics in order to guaranty that the requirements and needs, expressed conjointly with the ASD experts, are relevant, correct and that they can be integrated into the concrete prototype of the mimicry application.

The experimentations took place as three meetings with the two ASD experts, from the Cocci'Bleue partner involved into the EmoTED project, in their office. We used as resources the tree-based editor, the simulator and the printed screens mock-ups. The process was guided by our propositions constraints: 1/ modeling the game components, 2/ modeling the child profile and scenario, 3/ simulating game sessions. All the fictive elements were collectively discussed and approved. The game elements analysis was informally performed during the 3 previous steps (confirmation of relevance as well as highlighting of issues). A formal experimentation review was written after each session. Sessions end with some issues and solutions we have to take into account for the next incremental version.

We realized several meetings because our process requires a specific reingeering-time. If changes occur on the initial metamodel we have to generate again the tree-based Java code. Because of the model separation into two parts, the model specifying the game components is still in conformance with the metamodel whereas the second part will be specified again during the next experimentation session. In the case of changes about the game dynamics we also have to modify the simulator code.

The game sessions simulations tested all the game aspects: success/failure of mimicry activities, use of token economies, unlocking of stages, the different times from a children's perspective (cf. Figure 6): learning sessions, end of the game, new game+. Feedbacks from these iterative simulations have mainly highlighted the need for the *ratio* concept and the idea of 'new game+' and its realization with the adjustments of the token economies. Experts were enthusiastic to participate to these early experimentations.

6.2 Current VR prototype and ongoings works

Although it was not into the scope of our scientific researches we sketch the VR results from the other academic partner. As illustrated in Figure 11 they succeeded in integrating an existing webcam-based real-time facial-recognition system (Faceshift[6]) within a Unity-based environment. Concretely the casual webcam is exploited by a faceshift plugin that captures and detects the action intensity of up 30 facial muscles. Through a specific API, the 3D environment collects these information. After a translation of the Faceshift coding system into the FACS one [14] the VR prototype identifies if all thresholds of one of the six basic emotions are reached. In addition, the motion-interpolation technique is performed by the Faceshift plugin, on the basis of several cartoon-oriented 3d-facial models, in order to animate both avatars: one directly with the real-time

[6] Website: http://www.faceshift.com/

facial measures, and the other for playing in loop a demonstrative animation of an arbitrary emotion.

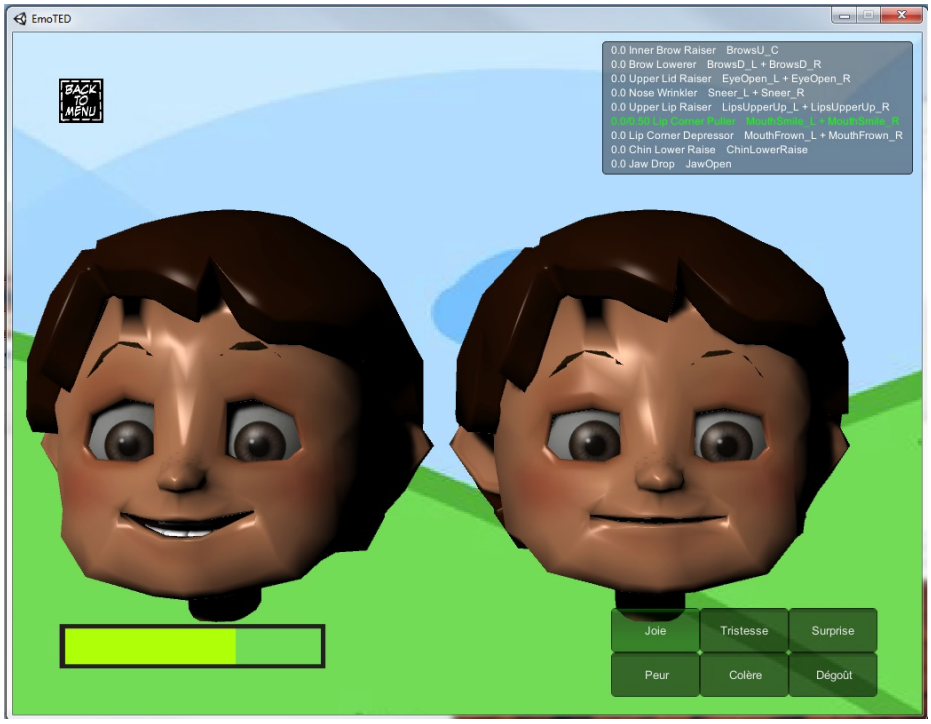

Fig. 11. EmoTED VR-prototype showing a system-controlled avatar and a facial-controlled avatar, both using a cartoon representation; detected emotion is highlighted in the bottom-right of the screen-caption; informations about the facial measures and thresholds are displayed in the top-right frame.

Mock-ups of the therapists' application have also been realized. The integration of the game design elements into the VR prototype was not initially planned and funded by the EmoTED project. New funding sources are studying in order to go further in the integration as well as exploring other facial-recognition systems (price and calibration criteria).

7 Conclusions and perspectives

The different results presented in this article are summarized. The original added-value of our double perspective approach, instructional design and Model Driven Engineering, is discussed. We also introduce the further challenges to tackle in order to continue this research work.

7.1 Contribution

Thanks to the context of the EmoTED project we had the opportunity to study and deal with the design of game mechanisms and dynamics in a concrete case-study. Our challenge in this multi-partner project was to tackle the gamification (study, design and validation) of a real-time facial-recognition & animation activity for the mimicry of emotions for children with ASD.

We concretely synthesis several studies about serious games for people with ASD, and more particularly studied several serious games for learning the mimicry of emotions for children with ASD. We also cope this results with some more general instructional design key-concepts in conformance with current best-practices from educational and behavioral therapies.

We also originally proposed to deal with the gamification design from a mixed *Instructional Design* perspective and a *Domain Specific Modeling* framework. The first perspective allows us to consider the mimicry application as a *Technology Enhanced Learning* environment that is set-up by providing a learning scenario taking into account the children's profile. The DSM framework considers the learning scenario as a model in conformance with a specific meta-model that formalizes the game mechanisms and instructional design elements as concepts, properties and relations. Thanks to the EMF tooling we proposed an iterative and incremental meta-modeling/modeling process to identify, formalize, and validate the game mechanisms and dynamics. Its originality comes from the ASD experts involvement. Indeed, they are co-designers of the proposals with the modeling experts. This approach has been made possible with the development of a text-based simulator that helps, conjointly with mock-ups of the future application, to simulate game sessions and interactions according to various parameters (specified within the learning scenario).

The first experimentations conducted in the EmoTED project show a great opportunity to involve experts in the early validation of the domain model. Indeed, the re-engineering time/cost is globally reduced thanks to the (meta-) modeling approach acting as a *Rapid Application Development* methodology for both the modeling editor, to specify the learning scenarios, and the simulator, to exploit and handle the models/scenarios.

7.2 Research perspectives

Design for and with children with ASD The main design pitfalls when developing serious games for children with ASD are related to shortcomings in reaching the therapeutic goals and to difficulties in designing an engaging and motivating experience for children. We then propose an inclusive design approach involving the knowledge of ASD experts and the experience of designers. The interests of children and their sensory profile are taken into account to customize the learning scenario according to the ASD experts knowledge based on their interactions with the children and their parents. Another further design step could rely on inclusive design methods involving the children. [25] proposes a method based on defining a model to integrate the expertise of clinicians, contributions

of children and experience of designers through a set of elicitation and merging techniques. The goal of their method is to design playful experiences that are effective in terms of therapeutic objectives and are enjoyable and engaging for children. At the same time their proposed method addresses the ethical concern related to designing for and with a population with special needs by including them in the design process.

Towards operational semantic formalization Although the simulator uses the model code generated by the EMF tooling, it is mainly hand-coded with very specific procedures based on the game dynamics. These dynamic semantics have been semi-formalized as UML activity diagrams but they can not be exploited for automatically generate all or part of the simulator code. A solution to this problem could reduce the engineering cost for the simulator development and capitalized the dynamics specifications. But how can we formally specify the dynamic semantics of a domain specific language? Is it possible to visually define it? graphically? And finally is it possible to leverage such models to partially generate simulators code? There is currently no widely recognized technique for defining this *operational* semantics of modelling languages, nor any specific technique for implementing simulation engines for such languages. A beginning of a solution could be addressed by the research works about the specification of *executable semantics*. [8] proposes to define it in terms of domain-specific actions, captured in a metamodel, and the scheduling policy that orchestrates these actions, in a Model of Computation. They propose an approach to connect these two models in relation to the abstract syntax of the considered language.

Acknowledgements

The project was funded by the *Laval Agglomeration support fund R&D 2014*. We thank our partners (ENSAM, Cocci'Bleue, LIUM) for their participation in the project. We are also particularly grateful to the ASD experts who participate to the collect of users' needs and the validation of our propositions.

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