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A new rehabilitation device: S'TIM, the persuasive and therapeutic serious-game for patients with dysexecutive syndrome

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ABSTRACT

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Among people with cognitive deficits, those with a dysexecutive syndrome are waiting for new rehabilitation solutions. Based on an extensive literature analysis, a multidisciplinary consortium has been created to specify and develop S'TIM, a therapeutic and persuasive Serious-Game played on a 48 inches robotised touch-table, which immerses patients in a virtual world through an elaborated scenario and various missions. This device has three main stakes. First, to break anosognosia so each patient could be intrinsically motivated and the actor of his own rehabilitation. Then, to achieve enough metacognition enabling the patients to build their own strategies and to select the most appropriate one in each situation. Finally, to facilitate the transfer of these strategies into everyday life. Changes in the schedule of therapists are also expected.

1. INTRODUCTION

This article will focus dysexecutive syndrome. After a reminder of the current rehabilitation methods offered to the patients, we will open up new perspectives with the specification of an innovative therapeutic tool based on the last technological advances and the possibilities it offers [1].

1.1 “Dys” troubles

The “dys” term is commonly used to refer to dyslexia. However, this term encompasses every trouble in connection with children learning at school and that impacts directly or indirectly adults both at a professional and a personal level [2]. Sometimes, it also leads to psycho-affective disequilibrium. This trouble expression is extremely variable from one person to another and depends on the social, cultural and environmental context as well. Six percent to 8% of the population is estimated to be concerned but studies reliability is low. Sometimes inborn, these cognitive disorders can also appear after different pathologies (*e.g.* stroke, head injuries and brain tumours). They can be classified in six categories according to whether there are specifics to writing language acquisition (dyslexia, dysorthographia), to oral language acquisition (dysphasia), to motor development and/or visuospatial functions (dyspraxia), to the development of attentional processes and/or executive functions (attention deficit with or without hyperactivity, dysexecutive syndrome) or to memory processes or numerical activities (dyscalculia).

The remainder of this article will focus on the dysexecutive syndrome.

1.2 A focus on the dysexecutive syndrome

Executive functions, or control functions, are implicated in cognitive processing requiring coordination of several sub-

processes to achieve a particular goal [3]. These processes are involved when it is necessary to be focused on a task, to memorise and to handle information, to adapt to unusual environments or rules and more generally when habits and reflex actions are insufficient [4]. For example, when the usual route is up for re-construction, another way must be found. These functions are also linked to some attentional processes as information selectiveness, attention division (mostly in multitasking, for example to think about the shopping list while being focused on checking if there is no car when crossing the street). Usually, they are set up during childhood [5], but they can be deteriorated thereafter. The dysexecutive syndrome concerns among others 40 to 60% of stroke victims, Parkinson' patients, people with attention deficit with or without hyperactivity and victims of head injury. The following functions are impaired (Figure 1):

- Inhibition, which consists in the voluntary control of answers, behaviours or distractors. With inhibition, an appropriate social behaviour is displayed in various contexts (non-impulsiveness in the case of the behaviour);
- Updating, which favours the encoding of relevant information and mental operations [6];
- Shifting, which is the adaptation of an action plan depending on environmental requirements. Shifting is also required to switch from one task or behaviour to another one (otherwise, perseveration is observed);
- Planning, which is necessary for the temporal organisation and for prioritizing strategy steps to achieve a goal (anticipation and projection);
- Strategies elaboration (cognitive and metacognitive), which enables to choose the most appropriate way to achieve a goal;
- Attention, which makes the maintenance of the action plan possible until its effective realisation.

Patients affected by this syndrome are frequently unaware of their difficulties (anosognosia). Their autonomy is highly

compromised and most of the time they are unable to return to their family and work lives.

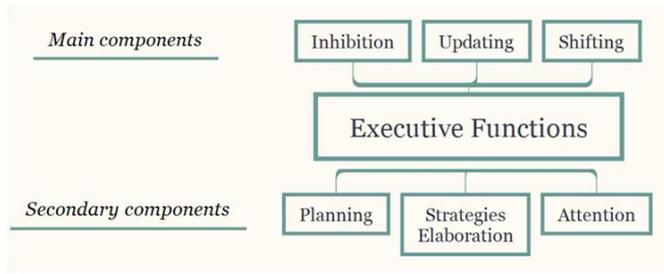


Figure 1. Executive Functions cartography [7]

2. REHABILITATION CARE

Patients with a dysexecutive syndrome mainly deal with occupational therapists, neuropsychologists and speech therapists for a cognitive rehabilitation process. The attention (selective, closed and divided) is a *sine qua non* condition because without it, any action on another point is hard. It reinforces stimulus detection capacities and increases swiftness [8].

2.1 Usual cognitive rehabilitation process

Patients frequently face significant difficulties in everyday life. Incompletely evaluated by usual neuropsychologic tests [9], executive functions impairments can prevent patients autonomy and the going back to their daily grind. Consequently, it is crucial to quantify these troubles and their consequences in the patients' activities of daily living (ADLs). On a cognitive plan, tests come from the GREFFEX battery. Thereafter, rehabilitation exercises are performed on papers (e.g. Scattergories, logical reasoning tests) or through board games (e.g. Connect 4, Who's who).

As the transfer rate of the skills with the conventional exercises on ADLs is very weak, the question of their ecological validity prove to be very delicate [10]. Indeed, during recovery exercises, patients mostly face a single task, strongly initiated by therapists. They have few real choices that are not representative of ADLs complexity where executive functions have to be fully used to elaborate strategies and engage appropriate behaviours [11]. However, ecological situations are initiated in rehabilitation centres to let patients take their own decisions while therapists take care of them. We can quote the Martin shopping test, the Multiple Errands Test [12] or the use of therapeutic kitchens or apartments.

Unfortunately, these practices are hard to implement nowadays because of the legislation (patients security), the cost (mainly for the therapeutic apartment), and from a human point of view because therapists take care of several patients at the same time, so activities requiring constant supervision are difficult to set up. Moreover, anosognosia is difficult to withdraw and is an obstacle to patient implication, knowledge transfers and the use of external assistance or compensation strategies. Finally, paper tests are restrictive (long and stressful for patients, impossible in case of illiteracy or writing difficulties). Situations are hard to standardise and measures are rarely objectified.

2.2 Actual technological devices

Nowadays, in order to provide new solutions, therapists turn toward video-games, that have been shown to be beneficial for cognitive functions stimulation [13]. Cyberpsychology, which encompasses all psychological phenomena associated with or affected by emerging technology is dedicated to it.

The use of control systems with virtual situations integrates cognition more actively than paper or objects handling tasks. It also stimulates attention components and executive functions [14]. Immersed in a virtual environment, patients are more implicated and motivated.

Currently, video-games used for cognitive rehabilitation are mainly chose among general public ones or are specifically developed. Most of the time, they are played on tactile devices (tablets). Candy Crush, Fruit Ninja, hidden items games, break-out games (visual attention, planning and inhibition) and Connect 4 (strategy) are part of the first category. The second category is composed of therapeutic Serious-Games which mainly consist on mini-games specially developed for the rehabilitation of a single function. For example, Cognibulle [14] for children from 5 to 12 years old with ten mini-games to motivate patients in the realisation of cognitive tasks in a dynamic environment. Happy Neuron [15] offers in a similar way 41 exercises for people of any age, likewise ExoStim (<https://exostim.com>). Genius group (<https://www.curapy.com/>) goes further with Serious Games combining cognitive and motor work. Depending on the case, therapists care (neuropsychologists, occupational therapists, speech therapists) during use is scheduled or not.

Other more specifics applications were developed with virtual kitchens and supermarkets [16].

2.3 Limits and perspectives

It should be noticed that most of these applications are not ecological, very similar to activities on papers or with usual equipment and have basic graphics. Patients still must solve a single task (Connect 4 for example). Moreover, they are simple and redundant because of a lack of or a poor storyline and narration that harms patients' attraction and immersion. In this way, Serious-Games potentialities are not fully exploited.

3. A NEW DEVICE OFFER: S'TIM

3.1 Method and positioning

From these observations and in order to bring a new therapeutic device for dysexecutive syndrome rehabilitation, a consortium consisting of a clinical team (rehabilitation doctor, occupational therapists and neuropsychologist team from the Ramsay Generale de Santé Provence Bourbonne Clinic of Aubagne) and an academic team (Information and Communication researchers from Toulon IMSIC lab) was constituted, with the presence of a PhD student, also engineer in Cognitics (specialist of interactions between humans and technologies). The multidisciplinary of this team lead to in-depth analysis of therapeutic practices as well as virtual reality specificities in cognitive rehabilitation.

First, therapists' action is partly transmissive (especially in therapeutic education sessions) but also mostly didactic, through practical exercises. For a better effectiveness, patients must be attentive, relatively motivated, receptive and have enough autonomous learning to acquire knowledges, social skills and *savoir-faire*. If they are at the heart of the process, they can elaborate their own cerebral construction resulting from their activities, organize more and more their world and be adapted to it. Interactions with therapists also allow co-construction and co-elaboration of knowledges. Learning conditions highly influence not only the acquisition or the restructuration of knowledges but also the development of the ability to learn, to understand, to analyze and to master tools. Therapists pass knowledge but proceed to put it into interactivity as well. In this way, learning process prompts the emergence of evolutionary processes and fosters the creation of a zone of proximal development (ZPD): things the learner will thereafter be able to accomplish alone, after having first explored them with the assistance of others. Therapists should more likely be guides who would create this ZPD, a broker, an intermediary, a mediator [17]. According to Bruner, the transmissive model would not allow the learner to become autonomous, to acquire a judgment or self-assessment capacities.

A temporary tutoring process should be necessary, with an enrolment aspect to generate interest, a dynamizing aspect to increase the goal perception and an encouraging aspect to maintain motivation. Assistance withdraws gradually to allow the patient to become autonomous. Furthermore, socio-cognitive conflicts have a strong formal learning aspect as far as they are discussed and are subjected to an explanatory action with therapists.

At last, interactions with therapists are essentials to give to patients metacognition capability (person capability to think about thinking and the self-awareness of it [18]). Like that, each patient learns to learn and have a prospective and retrospective view of its own process. New mediations can be used, including the Theory of Mind [19]. In a therapeutic context, a work on the awareness of the differences between appearances and reality as well as on the metacognitive representation of our own skills allow a better understanding of other people's minds, to increase self-confidence and to improve social skills.

Furthermore, the rehabilitation process is long and hard. As it is essential to succeed, patients have difficulties to stay motivated and implicated. In psychology, motivation is considered as a biologic, cognitive and social regulation center. It is the energy and the sense of people perseverance in their acts and intentions root. The auto determination theory [20] highlights three basic needs at the origin of this motivation: competence, relatedness and autonomy, the latest having the most impact. People more likely integrate experiences when they can express these needs. An intrinsically motivated activity (antiterminated regulation) is performed only for fun. An extrinsically motivated activity is completed for external reasons (reward or fear of a punishment). If the need for autonomy is filled by an intrinsic way, the chances of sustainable learning, performances, persistence and creativity are higher [21].

In the light of what has been explained above, a serious-game (SG) seems to be an interesting tool. As a video-game, it is based on rules and constraints, directed toward a clear objective which implicate ludic problem solving and feedbacks that allow players to monitoring progress until the

goal achievement [22]. Moreover, if a persuasive dimension is added, ludic problem solving is performed to provoke behavioural, socio-cognitive and socio-affective changes [23]. Challenges must be motivating, adapted to each patient and of increasing difficulty. Repetition imposed by operant conditioning, playful in this case, is less boring and tiring [24]. It also improves self-efficacy and self-management skills which reinforce motivation. Patients identify and embody avatars, their use leads then to an improved investment [25]. Patients can as well understand different social roles that will develop their empathy and their learning of understanding other's point of view and feelings. Social learning should be easier.

A balanced SG (between challenges, playability and patients' knowledges) allows immersion, satisfaction [26] and an intrinsic motivation with pleasure, interest, performance, good learning quality and self-confidence. High performances and unexpected level of consciousness are observed as results [27]. At last, a developed narration transports the patient and leads him to be more sensitive to the influence of the story message. If all the conditions are completed (entertainment, immersion, interactivity, transportability) patients can reach the "flow", the optimal experience. Cognitive resources allocated to the SG and motivation increase, which makes knowledge changes easier [23].

3.2 Device specification

Based on these data, the consortium specified S'TIM, a persuasive and therapeutic SG which favors motivation and patient' autonomy and facilitate mediator action for therapists. With a view of accessibility and a need of adequation, an ergonomic approach of user-centered design has been set up for all SG aspects (technical and visuals for the interfaces).

At the beginning of the first session, the patient has the possibility to choose the avatar he will embody all the way. A highly developed scenario has been developed to transport him into a deep universe with a captivating narration, which will make him more sensitive to the therapeutic message. He will have to accomplish various challenges, of increasing difficulty easily adjustable by therapists. During his journey, he will meet some characters, each of them with his own personality. By interacting with them, the patient will develop his empathy and his social learning. Omnipresent, the therapist will be able to decide if a real reflection has been made and if a strategy is acquired. In this case, he may validate it by a strategy medal. He also will be able to observe patients with detachment. At the end of each session, a debriefing between the patient and his therapist will allow them to go back to the experience, actions and feelings of the patient and to favor new knowledge transfer into everyday life [22].

The medium is a robotized 48' robotic touch-table with capacitive technology and high contrasts. Its height is adjustable to allow interactions seated or standing and reclining so each one can comfortably work. It is easy to use regardless of the age, the familiarity with technologies or the presence of a wheelchair.

Finally, each detail has been approved by the whole consortium. The implication of patients and therapists from the beginning of the process of specification reduced objections and rejection risks. At each step, iteration allow to

check if users' needs the need adequation are respected and to adjust the rest of the project (Figure 2).

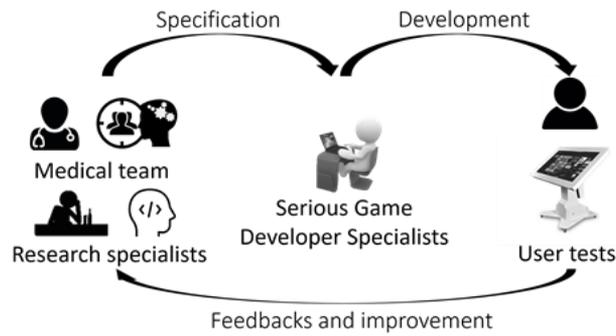


Figure 2. Specification process

In conclusion, the S'TIM SG will fulfill three objectives. First, the self-recognition of the troubles by the patients. Then, to achieve enough metacognition to enable the patients

to build their own strategies and to select the most appropriate one in each situation. Finally, to facilitate the transfer of these strategies into everyday life (Figure 3).

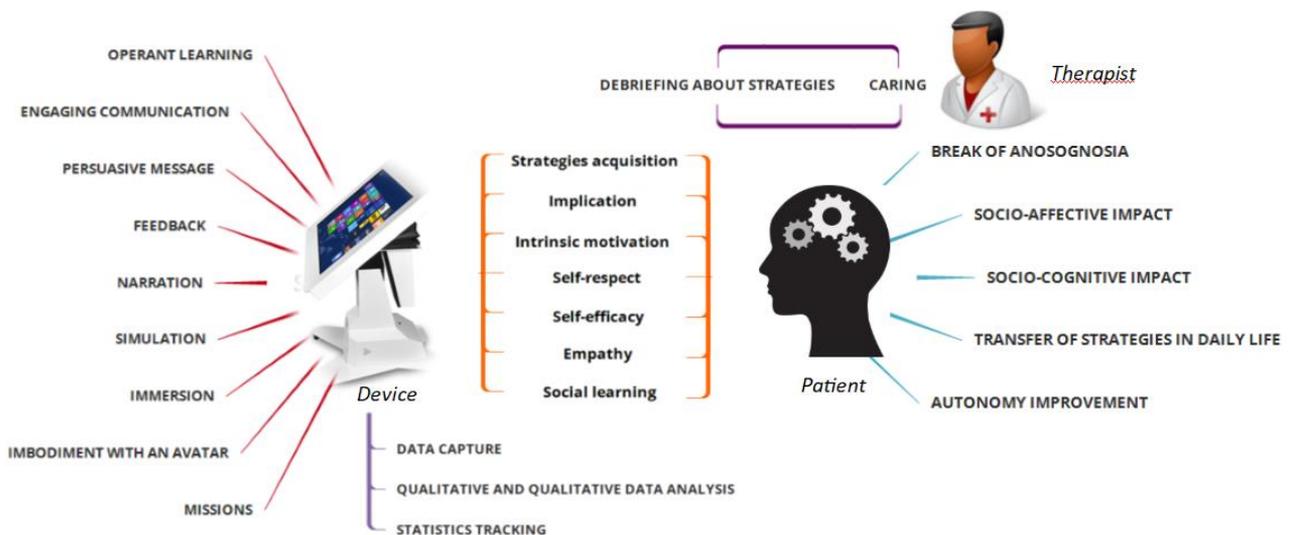


Figure 3. Characteristics and expected impact of the S'TIM device

3.3 Device overview and first feedbacks

The specified device is still in development but is nevertheless usable. Patients are immersed in a realistic virtual environment where they play a character who wants to leave his city to join his friends in a paradise island. The first scene takes place in a house (bedroom, living room and kitchen) where patients must find and collect specified objects. They can move with an ergonomic game pad at the bottom of the screen (figure 4).



Figure 4. Screenshot of the room

In the second scene, patients have first to find their bearings on a map in order to explore the city and meet a character who is waiting for them. Progressively, over the ten scenes and various tasks, they must face troubles related to their executive disorder. The progressivity and the repetition of tasks in different contexts avoid weariness while allowing the repeatability that is essential for skills development.

Simultaneously, data are collected (e.g. number of useful and non-useful clicks, heatmap, inactivity and activity periods, perseverance) and viewable in the therapist interface of the device. Therapists have access to data summary and can add comments and follow overall progress. Up to now, users (about thirty therapists and patients from 16 to 82 years old) did not identify difficulties in the appropriation of the device, and they actually were very enthusiastic and implicated in exercises. Patients were receptive and motivated during quick sessions lasting five to thirty minutes. By now, therapists have a pleasant and easy to use new tool for their practices.

4. LIMITS AND PERSPECTIVES

The huge device S'TIM is still in development and should be completed enough by autumn 2018 for a multicentric clinical study focused on its acceptability and pertinence for dysexecutive syndrome rehabilitation (3 implicated clinics). The impact of the use of S'TIM will be evaluated on several levels: cognition (MOCA, BREF, TAP, attention questionnaire), metacognition (PCRS questionnaire), behavior (DEX questionnaire of the BADS) and mood (HADS scale). The articulation between goals, users and technology will provoke an organizational change [28] which will also be studied. To introduce this new device, there will be a specific accompaniment to sensitize therapists and facilitate their appropriation before its full integration in practices. Feedbacks will be precious for the future because therapists have a fundamental role with patients. They will have the possibility to devote full attention to knowledge contextualization to favorize transfer in everyday life (didactic and not transmissive action). Moreover, quantitative and qualitative data analysis, impossible before, could improve their understanding and care.

Finally, for patients with low harm mobility or big neglect syndrome, it is possible to reduce the size of the window. To avoid visual fatigue with the screen, we recommend to adjust the time depending to patients and to not exceed 30 minutes.

5. CONCLUSION

This innovative approach is a huge multidisciplinary challenge with major issues for patients with dysexecutive syndrome. Theories from Information and Communication sciences, Educational sciences, Cognitive sciences, Psychology or Neuropsychology are involved in the design. With therapists' implication, S'TIM will create an opportunity to improve patients' autonomy, to put them at the heart of their rehabilitation and to give them a chance to go back to their everyday life.

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