Using Serious Games for Cognitive Disabilities

Rita Marques Tomé[1], João Madeiras Pereira[1], and Manuel Oliveira[2]

[1] Instituto Superior Técnico
Rua Alves Redol 9, 1000-029 Lisboa, Portugal,
rita.tome@ist.utl.pt, jap@inesc-id.pt
[2] Highskillz, London, United Kingdom
manuel.oliveira@highskillz.com

Abstract. Serious games have increasingly become a good option with regards to professional training. However, the majority isn't appropriate for people with cognitive disabilities, since there are several obstacles when developing for such a heterogeneous population.
This paper's objective is to contribute for the development of serious games for people with cognitive disabilities by presenting a list of recommended design principles, collated from recent literature. A strong emphasis is placed on the adaptability of games since this is an important characteristic that ensures the game can be configured to fit to the needs of each player, minimizing the obstacles encountered and providing a personalized environment for learning.
In some cases cognitive disabilities can have motor control implications and consequently the traditional devices commonly used may not be the most appropriate for this population. In order to help developers choosing an adequate device, this paper also surveys and compares the most common devices used nowadays for serious games.

1 Introduction

Serious games' primary objective is not pure entertainment, but passing some kind of knowledge to the users. Typically they unfold in an environment that is a simulation of the real world, where the player must solve one or more problems.

By using this kind of games, the user can test several behaviours [1] that are considered too risky with undesirable consequences in the real world, either for the user's physical and psychological well-being or that of others. The user learns and develops the best approaches to the problem presented within the game and, as a consequence, when confronted by the same in a real situation, they have a greater probability to act accordingly [2]. Several studies (see section 2) show that there are many benefits from using serious games for rehabilitation of people with cognitive disabilities.

1.1 Serious games and cognitive disabilities

In people with cognitive disabilities have difficulties, the functions of attention, memory, reasoning, language, perception, problem-solving, conceptualizing [3], self-regulation and social development [4] are impaired, not allowing the proper knowledge acquisition and competence development. Therefore, they have great difficulty in relating and learning concepts and behaviours. In addition, expressing themselves through writing or speaking is equally challenging, thus having implications at social level. As main examples of cognitive disabilities, we have Fragile X Syndrome, Down Syndrome (also known as Trisomy 21) and autism spectrum disorders (such as Asperger syndrome).

Individuals with such different characteristics than those we are used to deal with, will require, therefore, dedicated attention. Traditional teaching methods often do not apply because learners lose interest quicker and more easily than those not cognitively challenged. Also, we have to take into account that cognitively challenged people do not deal with pressure in the same way as others, being important to provide them not only the pressure-free environments traditional methods typically don't entail, as well as stimulating and innovative environments that capture their attention and motivate them to activities of learning [4–6]. This appears to be an untenable paradox, but the use of serious games is a viable solution. However, the vast majority of serious games can not be used by the cognitively challenged individuals because these games take advantage of capabilities that some of them don't have or that are not developed enough, such as reading and writing skills, identification of objects and colours, manual dexterity, among many others. Another barrier is that these games also do not provide the adequate interface and contents of the activities [7]. Even what has been specially developed with this focus is insufficient, since it is mostly simple didactic units and not full games [5], based on 2D graphics [6]. Most of them approach contents in a tightly scoped manner as in the case of like social skills (personal hygiene, appearance, clothes, kitchen utensils and rules), cognitive skills (colours, shapes, order, differences), written language and numeric skills (decimal numeration, addition, subtraction) [6], but let out ore complex situations like everyday work life.

The use of serious games is fairly accepted by this population because they do not feel the pressure existing in the real world, feeling comfortable to explore the virtual world. Furthermore, they feel that there is no risk in testing various behaviours at their own pace, obtaining an immediate feedback on their actions [3, 4]. For a person with special needs, the risks are related to insecurity about their abilities, anxiety to deal with various situations and fear of social rejection when they fail to fulfill the tasks proposed. The risks can be disseminated through the repetition of tasks to be mastered, increasing the confidence of the individuals and thus improving the social relationships they establish with other people.

Most users with disabilities also have a (sometimes very high) attention deficit, which greatly hinders learning. The use of serious games has the advantage of being able to capture and keep their attention on the tasks, reducing this problem[1]. In addition to the advantages mentioned, the games allow the development of motor coordination and spatial orientation [2], [5], allow the represented situation to be played under the same conditions, can be adapted to individual person needs, can be interactive and used individually or in groups [4]. Also, since the computer is recognized as an important tool in our society, impaired people feel proud to be using it as well, having increased confidence and self-esteem [8].

2 State of the art

In 1991, Burt et al. [9] published a report presenting the case studies of four adults with autism that participated in a work-training program, each one with widely varying inabilities to retain a job. Each person had a specifically developed training plan, meaning that the tasks proposed had in mind the inabilities of each one, but also their personality and their qualities. For instance, two people presented a ritualistic behaviour while walking and the approach to each case was quite different: one of the subjects was extremely time-conscious, therefore he was given a detailed task schedule as a form to control his ritualistic behaviours and encourage self-control; for the other subject with ritualistic behaviours, the best approach was to film him and other people walking, so that he could compare both ways. Despite the personalized approaches, both had also a checklist with the desired behaviour and rewards associated, in order to teach them self-control. This report shows us the need for adaptability and personalization of approaches, even if they are aimed for people with the same diagnosed pathologies. For instance, two users with Down syndrome may not react in the same way to a game (even if it is specially designed for people with Down syndrome), which depends on the disabilities they have but also in their interests and existent capabilities. The diagnosis of the pathology is a mere indicator of which characteristics the patients might present, and does not mandate that all patients present all characteristics. Therefore, in the next subsections we survey some recent serious games that define adaptability as an important feature and present the advantages and disadvantages of some of the most common devices.

2.1 Software applications

eAdventure, by Torrente et al. [2], is a game platform specially designed for the development of games whose objective is to improve professional education of people with cognitive disabilities. In this project, two games were developed with eAdventure: “My first day at work” and “The big party”, which are *point-and-click* adventure games. This game genre was chosen because it doesn’t present many frequent accessibility barriers and has significant educational potential. Since reflection predominates over action, these games are low-paced and only require simple inputs, specifically mouse clicks. The game genre is an important factor towards a successful learning experience, since the choice of the wrong genre can actually worsen the users’ condition. For example, First Person Shooters (FPS) games may have negative effects on people who have attention disorders and impulsivity [1]. It is noteworthy that the platform eAdventure also allows a personalized game experience, where the content and puzzles can be adapted and the complexity and number of objects present can be changed as needed.

In the game “My first day at work”, it was noted that participants with severe disabilities had some trouble in remembering short-term goals, which suggested the need for a task-list feature accessible at all times in the game. Also, it was found that many users didn’t identify themselves with the game, which is a problem, since they may not be able to play as they wouldn’t understand what is going on in the game. The best solution would be to use the players’ own images in the virtual avatar, but it was too complex to implement. In the game “My first day at work”, the solution adopted for this problem was providing the player a set of avatars with different abilities and characteristics, from which they chose the one with whom they identified the most. As the game “The big party” was a first-person game, the players only chose their gender.

Although the game developed by Cagatay et al. [10] is focused on speech disorder children therapy, it has some interesting aspects, mainly the ability to adapt to the needs of each user, similarly to the work of Torrente et al. [2]. This can be achieved due to the hierarchical structure of the game, where “an object can be added to any scenario part, a scenario part can be added to any scenario, a scenario can be added to any story.”. There are several characters available and 25 different objects, including trash can, swing, slide, balls and boats, which have their own functionalities. There are also a variety of scenarios, like a park or a child room. With this game, it is possible to arrange various interaction settings by changing the set of objects and characters to be included in a specific scenario. It is also possible to change the actions each object offers, such as the ball rolling or bouncing and the swing swinging. The variety of functionalities of each object increases the user’s attention and avoids him/her getting bored.

A similar work was developed by Hussaan et al. [11], which created a system capable of generating adaptive scenarios taking into account the user’s profile and the user’s interaction traces. The interaction trace is the history of the user’s interactions with a computer and allows to detect the evolution of the user’s competence. With it, we can detect if the user is stuck in the game and, if they are, provide adequate help, like hints, or even modify the scenarios. Also, the system can adjust the level of difficulty of the game, so that it is not too simple neither too difficult, and make sure the same exercises are not repeated too many times. The user’s profile is also useful to know which kind of resources a user prefers, giving primacy to their placement in the scenarios.

The application Picaa, developed by Fernández-López et al. [7], also allows this adaptation of the game characteristics to the user, specifically “the number of components or concepts to be taught, screen composition, screen position (rotation or not), multimedia used to represent the components, difficulty level (goals of the exercise, working out the punctuation), reinforcements and help to the users. This is done by means of a template, which specifies the adaptations necessary for each user, like in Table. 1.

Table 1. User impairments and possible adaptations [7]

User limitations	Adaptations
Visual	Colors, size, contrast, magnification.
	Do not use color as information
	Conversion of graphical information to text and use of voice synthesis
	User interface components accessible by means of mouse, keyboard or tactile device
Hearing	Alert sounds coded as text or graphic
	Adapted vocabulary
	Use of subtitles and language of gestures
Mobility	Adapted input and output devices
	Alternative selection of components (alt-keys, voice as input, scrolling…)
	Time of scrolling, time for user selection, pace of the application
Cognitive	Simple interface without distracting elements
	Priority use of graphics

If and when the activities are tried out don't fit the user needs, the user profile can be changed so that the software can be re-adapted to fit the user's needs. Changes include the format of content to be accessible (image, text, sound), interaction with the content (requiring more or less fine motor skill), or screen size.

Bartolomé et al. [12] present a serious game used to promote social skills of people with neurological development disabilities. It is specially developed for people with attention deficit disorder, a very common characteristic in people with cognitive disabilities. An important aspect to consider is how the targeted users react to software: for the younger ones (10-13 years), the most attractive components in the game were the interface and the rewarding system (with medals); for the older adolescents (14-16 years), what was deemed most attractive were the dialogues and social interactions that caused more impact, probably because they were more familiarized with video games than the younger users. Considering the disparity of preferences in a group of children with ages relatively close to each other, one can expect an even greater disparity when considering an adult population, with a wider range of ages (15-64 years). Despite such comparison, designing video games for adults is actually very different from designing them for children, since each group has its own interests and way of thinking. This was clear in the study of Robertson and Hix [8], where the users (men and women aged 25 to 60) were confronted with a child's game. In the whole group, only one user was able to achieve the game objective. Another user didn't even try to play and two other simply said the game wasn't fun. Although, when they switched to Solitary (present in Windows operating system), their reactions were much more favourable, probably due to the fact that they perceived it as a game. Also, Solitaire has a feature that might seem very simple for common players, but that was very attractive to them: each time the cards are dealt, the pattern of the back of the card deck changed. It was a subtle visually attractiveness and, in addition, it also brought something new (but not too new) every time the game was played. It's important to notice that this change was subtle, otherwise some players could feel startled by it and not receptive to the game.

In general, users rejected action-based games and those games where it was required to avoid being attacked (since to their frustration, they were rapidly eliminated) but, on the other hand, Hangman, Wheel of Fortune and Solitaire were popular games among the group.

Total Challenge, by Martins et al. [4], is a serious game developed for people with mild to moderate intellectual disabilities that monitors their evolution with respect to memory, decision-making time, capacity of observation, learning and applying knowledge. It can be played both on-line and off-line. The greatest difference between both modes is that in the on-line mode, the player competes for a place in the on-line ranking, which usually results in higher motivation. In this mode, the rules (that is, maximum time response, number of rounds of each level) are the same for all players, depending on the level. However, for training purposes, the off-line mode is better because it allows the adjustment of the referred rules for a given user. The score acts as an incentive to achieve better results than the prior ones or better than other players, when playing on-line. When the player fails, it receives a motivation message encouraging him to play again and get a better score.

The feedback voice used in this game is friendly and fun and can be male or female, according to user preferences. Each feedback message is complemented with motivation or call attention phrases like "Congratulation, go like this" or "Be more attentive".

The studies presented in this section are briefly summarized in Table 2, thus providing a simple comparison of their main characteristics.

Table 2. Summary

	Game genre	Age range	Educational Benefits	Target pathologies	Adaptability
eAdventure	Point-and-Click	15-64	Professional Education	Cognitive disabilities	Yes
Speech disorder game	—	0-14	Speech therapy	Speech problems	Yes
Project CLES	Adventure	All	Cognitive skills	Cognitive disabilities	Yes
Wii Test Gaming	—	10-16	Social skills	Attention deficit disorder	Yes

2.2 Devices

Building successful games for the cognitively disabled is not only about the software, but also about the hardware that supports the interface. Consequently, it is important to study the usability appropriateness of the more common devices (eg. mouse, trackball and touch-screen) for the target user population. Robertson and Hix [8] revealed that with touch screen the drag-drop times were the fastest, whilst the trackball registered the lowest ones. Nevertheless, all users found the touch-screen tiring and the trackball was difficult to use, since it required participants to use both hands. Consequently, in this study, the mouse was the elected device for this population. However, in the study made by Urturi et al. [13], the participants were asked several questions about their preferences and was found that 70% of them prefer multi-touch screen to a screen with keyboard and 60% like using tablets with big screens instead of smartphones. A similar situation was detected by Saleh et al. [14], where it was noted that children preferred to use the touch screen feature instead of keyboard and mouse. This means tablet devices were preferred, since they allow multi-touch gestures and engage more than one user at a time, which enriches the social experiences of the users.

Fernández-López et al. [7] introduce software applications for iPod touch, iPhone and iPad, mainly because of their positive features:

- High-quality responsiveness multi-touch screen without the need of a stylus - some cognitive disabled users don't have the necessary skills to work with a pencil or stylus. This can be bypassed by the touch, since it is a natural interaction that requires no learning;
- Mobility - perform activities anywhere at any time;
- Design - just one button at the front;
- Different interactions - rotations or shakes can be interpreted as a user input, thus creating innovating interactions thanks to the built-in accelerometer; make use of forward and backward facing cameras, microphones and multipoint touch-screen capabilities [15];
- Accessibility - devices offer high contrast function, zoom and a gesture-based screen reader;
- Connectivity - peer-to-peer connectivity using Apple Bonjour allows to create an ad-hoc Bluetooth or Wi-Fi network, which is useful in supporting group work;
- Ease of acquisition - can be bought in any shop; their success in the marketplace facilitates continuity over time for this family of devices; relatively inexpensive [15];

It was also pointed out that the iPad allows the use of applications with groups for which the iPod touch-screen was too small. In addition, due to the bigger screen size, there's more room for user interface elements, permitting to show larger items that make it easier to see and touch. Moreover, all of the mentioned devices are socially accepted [15] and have associated an entertainment status, which is crucial to captivate the users. In fact, in some cases, users prefer to use these devices instead of using low-tech options [15].

The review done by Kagohara et al. [15] concluded that iPods, iPhones, and iPads "can be successfully utilized within educational programs targeting academic, communication, employment, and leisure skills for individuals with developmental disabilities". On the other hand, it also indicated that some users showed difficulty in operating these devices with sufficient finesse/motor control to activate the desired functions, thus suggesting that this might not be the most adequate hardware solution for people with significant motor impairments, unless it can be integrated with other solutions.

As an hypothesis to bypass the accessibility obstacles disabled people often face, Alqahtani et al. [16] proposed the use of multimodal applications, which allows the users to choose one method of input between speech, text or point-and-click. The use of speech in applications has advantages like the development of more natural interfaces, hands free access and increased user satisfaction (because it is a multimodal interface). With this kind of interfaces, even the people who lack manual dexterity (a very common characteristic among cognitively disable people), can play the game. This way, the interface also serves as an inclusion tool.

Since video consoles are specifically designed for playing, they present good alternatives to more common devices, like computers or tablets [5]. Hereupon, it is noteworthy the use of the Nintendo™WiiMote, which helps to make the target application seem a video game and not a therapeutic tool and can be used to overcome the small size of some touch screens. It is an easy to learn tool and feels natural to the user, since it uses body movements. Even more important, it allows people with different levels of motor coordination to use the software, another characteristic that also varies a lot between people with cognitive disabilities [12].

In the same line of thought, Nintendo DS™ is also a good alternative to common devices, due to its features: resistant (designed for children - doesn't break or get scratched with ease); has a good autonomy, circa 11 hours; has large memory; and it's not very expensive. In addition it has two screens, which offers more interaction possibilities than only one screen; has wireless connectivity and can be used with other commercial games, thus acting as a reward mechanism [5].

Costa-Pazo et al. [17] compared some other devices according to their suitability for both motor and cognitive disabilities, as we can see, in a summarized way, in Fig.3.

3 Design Principles

Based the analysis of several studies done in this area, we can establish a list of design principles recommended for an adequate development of serious games for cognitive disabilities, organized in 5 categories. This list aims to help understand which are the components in a video game that could influence the users, thus affecting their performance and their predisposition to learn.

3.1. **Interface**

(a) Design simply in simple layouts [4], [18, 19] to increase concentration of the users in the new information being presented [3];

(b) Use of minimal screen items, since more complex items diminish the acceptance of the software as a game [12];

Table 3. Suitability of Interface Devices [17]

Device \ Disability	*Motor*	*Cognit*
Trackball	*	*
Touchpad	*	
Joystick	*	*
Head mouse	*	*
Eye mouse	*	
Touch screen	*	*
Actigraph	*	*
Gesture remote	*	*

(c) The icons should be large [19], but not in excess. This helps users with fine motor skills difficulties [3];
(d) If the icons are too large, users are not sure about where to click [12];
(e) Use familiar symbols to the target population [3];
(f) Avoid the use of small objects in the game because they take some time to be recognized by the user [14];
(g) Grouping of icons should be logical and realistic [12];
(h) Icons should be properly spaced to avoid wrong selections [12];
(i) Instructions and buttons should be clearly displayed and always in the same place [3];
(j) Implement a fixed game window, as a way to prevent users from resizing it unintentionally (constitutes a cause of frustration) [12];
(k) The concept of menu bar might not be understood by the users, especially if it contains words, because some users may not be able to read them and understand the concept beyond [12];
(l) Don't use pull down menus, which are not understood by this population, due to motor control and cognitive problems [12];
(m) Colours should be in harmony with the overall interface, while ensuring sufficient contrast for people with limited vision [2], [14], [18];
(n) Changes in colour or graphical environment can help to maintain the user's interest for a longer time [1]. This can be done periodically or as a consequence of some user action;
(o) The game should require only simple commands to change the content easily [7], [19];

3.2. **User control**

(a) Give enough time for the users to read and analyze the available information and to make decisions, since they react slowly and move icons with careful gestures [2], [7], [12], [18];
(b) Must be relatively slow games and not require the use of many controls [2];

(c) Should allow users to go back in the game - especially for users who have information processing and/or memory difficulties [3];
(d) Enable user customization based on user preference - enable to slow speed down, use keyboard access, etc. [3];
(e) Help users navigate, by informing them where they are. In order to do this, place navigation information at the same place (ensuring it is consistent and simple), use maps when appropriate, use home and back buttons and provide context information. Emphasis on the use of graphics [3];
(f) Design in ways that minimize the skills and abilities required to navigate [3];

3.3. **Identification with the game**

(a) Must give the user a sense of identity, principally through the main character (gender, set of disabilities, physical characteristics, etc) and by creating interesting stories to users. They also evoke empathy and captivate the users [2], [20, 21]; An example are the characters developed by Brandao et al. [22], Betinho and the baby Samuca;
(b) The game should provoke emotional reactions [21];
(c) Interaction mechanisms should be designed according to the profile and cognitive limitations of the player. The game should be as configurable as possible in order to meet the needs of everyone [2], [5], [7], [14];
(d) The game should be designed according to the cultural environment of the player [14] ;

3.4. **Feedback**

(a) Language should be simple (preferentially plain text), clear and direct [2], [18];
(b) Use native language [3];
(c) Avoid dense blocks of text [3];
(d) Every action should have feedback and it should be given through several ways: visual, auditive, subtitles or sign language [2], [18, 19];
(e) Feedback can be given by numerical scores, progress bars, character dialogues, sound, vibration of the controller, etc [4];
(f) Since this population has communication difficulties at both vocabulary and comprehension levels, the feedback should use sounds, specifically spoken language [7];
(g) The feedback should take advantages of the stronger intelligences/capabilities of the user, which are used to improve the weaker ones [5];
(h) It must not create any kind of frustration, which is very negative to the player. The errors committed should be corrected without discouraging the user and without repetitively penalizing them for the same failure [5], [18];
(i) The feedback should be used as a rewarding mechanism that can provide the increase of motivation and satisfaction of the user, resulting in a higher desire to complete the tasks [4];

(j) The game should let the user commit errors and learn from them based on the game responses to the user's actions [14], [18], [21];
(k) The player should be recompensed for making the correct actions. This can be achieved by gifting him with things he likes, including: animations, musics, videos, points and objects in game (for example, trophies, clothes for the character, etc.) [1], [4], [5], [14];
(l) The value of the gift should depend on the users performance (based on the time spent on the game, number or correct selections, etc.) [14];
(m) The feedback can be related to the learn action/concept, improving the learning by imitation [5];
(n) Show the user's current results and the next problem to solve [18];

3.5. **Transmission of concepts**
(a) Should be given preference to the use of photographs or realistic drawings, due to the difficulty of abstract thinking of this population. If the game is designed in a *cartoon* style, should be complemented with photographs and videos of real environments [2], [6], [12];
(b) The images used should have a large size [14];
(c) It's recommended the use of 3D graphics [6];
(d) The game should have good graphics because it captivates the users and its realism and similarity with reality facilitates the association between virtual and real world [2], [12], [18];
(e) The educational contents must be introduced in the game in a dissimulated way, causing an indirect learning and minimizing the cognitive load pace. This way, the game will be recognized by the users as such, not as an educational software. Therefore, the game should have objectives as a learning tool and objectives as a game [1], [5], [12], [18];
(f) Problem solving in the game must follow the same sequence it would have in the real world, in order to facilitate transfer of learning from the virtual world to the real world [2], [5], [18, 19]
(g) The user should be guided step-by-step through the decision making process. This could be achieved using another character of the game, like the director of a Zoo [21];
(h) Actions should reflect real life situations, especially when manipulating objects. For instance, it is more realistic to drag-drop objects to select and move them, than just clicking on them [12];
(i) The learning process should be based in levels or missions, in which the degree of difficulty should increase gradually and the cognitive weakness should decrease [5], [14];
(j) "Work on the association of ideas, building relationships between concepts, sorting sequences of steps" - use the cause and effect paradigm [7];
(k) Including images and the respective name improves retention of the information [12];
(l) Preference is given to approaches with great interaction, contrasting with approaches with a lot of observing to do, but with an answer given with only on interaction (like a mouse click, for instance) [6], [7], [12], [18];

(m) Use animations, but avoid the ones that are too fast. Also, avoid the occurrence of too many actions in rapid succession because they can startle the users [12], [18];
(n) The game should offer a varying range of activities, to minimize fatigue or boredom [14], [18];
(o) Maintain balance between success and challenge [20]
(p) The game should transmit not only functional knowledge, but also social knowledge [14];

3.6. **Accessibility**
(a) Minimize skills needed to navigate within game [4];
(b) The more suitable game genre is a *point-and-click* adventure, since it has practically no accessibility barriers and has a significant educational potential [2];
(c) Don't include elements that can cause seizures, like elements that flash or have particular spatial frequencies [3];
(d) Use accessibility features, like sign language [18];
(e) Allow the use of different input devices, like mouse, keyboard and speech commands [2];
(f) Provide alternatives to text content, like audio and video, so that it can be changed according to people needs, such as Braille, speech symbols, other languages including sign language [3, 4];
(g) Aim for compatibility with assistive technologies, such as screen readers, text-to-speech, zoom features [3];

The presented design guidelines are useful, but to develop effective user interface is required also user testing because "Design guidelines cannot cover the details that need to be dealt with in fitting a user interface into a specific situation of use. Rather, developers must supplement adherence to guidelines with testing with representative users and tasks." [19]. User testing is important because designers and developers don't have much experience in working with this population, lacking real notions about their needs and capabilities.

4 Conclusion

Serious games constitute a great alternative to current therapy/training methods for people with cognitive disabilities. The problem is that there is a lack of appropriate games for this population, hence arising the need for developing new and innovative games that can truly capture the users and help them overcome (some) of their needs. Although, the development of technologies for people with cognitive disabilities finds several obstacles: "difficulty of addressing cognitive issues through technology applications, the underestimation of the needs and abilities of people with cognitive disabilities, or the cognitive disabilities being hidden compared with other conditions." [19].

With the right hardware and software, serious games can become one of the most useful and accepted tools among this population. Despite all pointed out, it should be noted that games can't reverse the users' situation. Games act merely as a tool to help disabled people to acquire knowledge [4], being essential "to achieve greater autonomy so that they can independently perform day-to-day activities. Dependency generates high social and economic costs, and at the same time it generates self-neglect, disinterest and isolation of the individual" [7].

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