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Digital Games for Down Syndrome Children's Language and Cognitive Development

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Abstract. Down syndrome is considered to be one of the most prevalent genetic causes of intellectual disability, derived from chromosomal disorder, which accounts for dysfunctions in many organs and has a characteristic phenotype, which consists of physical and behavioral features. Many studies have shown that language is one of the most impaired areas of function in Down syndrome and perhaps, the highest barrier for their substantial inclusion into formal education and community. The aim of this paper is to investigate the specific features of this linguistic phenotype, presenting the strengths and weaknesses of their language, as well as the factors that contribute to their formation, compared to normally developing children. In addition, it scopes to highlight the role of educational mobile apps, as innovative and interactive tools for the developmental learning of Down syndrome children. The results of the research indicate that their language goes through the same, with typical development sequences, but progressively erases a slowing trajectory and results in lower performance. However, the use of digital games, especially virtual reality video games, can, significantly, improve their cognitive and fine mobile functioning and also the acquisition of literacy, language and math skills, in order to upgrade their quality of life.

Keywords. Down syndrome, language phenotype, factors, digital games, video games, virtual reality

1. Introduction

Down syndrome is the most common chromosomal disorder with a frequency of about 1/800 births and affects 25-30% of people with intellectual disabilities [1]. It is also called trisomy 21, as 95% of this population has a third copy of all or part of chromosome 21, instead of the normal two copies, while the less common types of the syndrome are translocated 21 and mosaicism [2]

The mental retardation of the syndrome ranges from mild to severe, with an observed impairment of cognitive functions, along with increasing chronological age. At the same time, the pathogenic function of the genes of the extra chromosome 21 contributes to the formation of a specific phenotype of characteristics, related to health problems, cognitive and language deficits, neuromotor dysfunction and early aging [3].

With regard to language impairment, they show a number of selective deficits in expressive vocabulary, syntax, and speech comprehension and production skills, in relation to typical developmental children [4]. However, there is considerable individual variation, as each

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area of their language system is affected to a different degree, while their expressive language has greater deficits than the language of comprehension [5], which is influenced by chronological age, non-verbal cognitive ability and the state of hearing. The intelligibility of their speech, the difficulty in combining words into sentences and further in classifying their thoughts and ideas, are responsible for their social immaturity, resulting in them experiencing frustration, anxiety and insecurity more often [6]. Furthermore, their difficulty processing information is attributed to their poor near vision and auditory deficits, while limitations in their fine motor skills affect their interaction with technology.

However, the researchers' interest focused on the qualitative differences they show in the learning process, such as the high individual variation in performance and the avoidance strategies they develop, such as their distraction and lack of motivation [7].

On the other hand, nowadays, ICTS promotes the development of hardware and software for digital games and particularly video games, that pique Down syndrome children's interest, focus their attention and motivate them, through the variety of audio-visual stimuli, to develop motor and literacy skills [8], designed exclusively based on their own needs and adapted to their own learning strengths and limitations [9]. Additionally, research has shown that virtual reality video games, with educational content, can enhance cognitive skills and motor coordination, as children move their hands on the screen to perform the interactive and interesting game activities. Thus, Down syndrome children's literacy skills emerge, through gamification techniques, i.e., providing points and rewards, in a particularly attractive way [10].

The present literature research aims to investigate to what extent and how the developmental language learning sequence of Down syndrome children is different from typical development and therefore, it examines the evolutionary process of the various areas of their language, compared to typically developed children, and how the particular features of the syndrome, as well as other factors, contribute to impairments in specific areas of their language system. Moreover, it examines the effectiveness of learning and practice through digital games/virtual reality video games, when incorporating appropriate and suitable learning theories and facilitating the more personalized learning, in order to optimize their linguistic and cognitive development.

2. Clarification of concepts

2.1. Definition - Types of Down syndrome

Down syndrome was named by the British doctor Down (1828-1896), replacing the term "Mongolism", which was used to describe mental disorders, considering that the Mongols were more prone to them, compared to other ethnic groups [11]. He contributed significantly to the epidemiology of the syndrome, continuing the epidemiological studies that began in the mid-1800s, in which several doctors described the special characteristics of this group of patients with mental disability, among which the fact that they were short and prominent and they had flat nasal bridge, hypotension and a protruding tongue [12].

Down syndrome or trisomy 21 is a chromosomal disorder, characterized by mild to severe mental retardation and a range of physical and medical impairments due to the presence of an extra chromosome 21, which can be attributed to three possible causes. In "trisomy 21" (92-95%), the egg or sperm develops with an extra chromosome, resulting from the fertilized egg obtained, having three chromosomes 21 instead of two. Separation failure, during the reduction of one of the chromosome pairs, usually occurs in women, while the frequency is higher in older ones. Thus, as the embryo develops, the extra chromosome is repeated in each new cell. In "mosaic trisomy" (2-4%), the probability of the extra chromosome

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results, due to the above condition, some cells having 46 and others 47 chromosomes. In "translocated trisomy" (3-4%), material from one chromosome 21 sticks or shifts to another chromosome, before or during conception. Therefore, the individual cells have two normal chromosomes 21, but also an additional chromosome material on the translocated chromosome [13].

2.2. Neurological profile in Down syndrome

The area of the brain of a Down syndrome child that is mainly affected is the cortex, both in neuronal density and in weaker neural synapses. Thus, as the child grows older, s/he will develop microcephaly with reduced brain volume, frontal and temporal lobes, cerebellum, myelination process and other areas of the brain with differentiated development. Particularly, the head of these infants has a larger third ventricle than normal developing infants, which is associated with the abnormal development of a wider area of the brain, such as the chamber, hypothalamus, or white substance of the brain, areas associated with cognitive processing and responsible for their cognitive deficits [3]. Moreover, they have abnormal neural interactions between the frontal and parietal lobes, which also affect the Broca area, while the abnormal development of the cerebellum creates problems of dysarthria, balance, synchronization and coordination of movements, as it is associated with executive function, reading, the sequence of learning, movement and language [13]. Also, due to the neurological development of the syndrome, from the age of about 35, they have the effects of the neuropathology of Alzheimer's disease.

3. Language development in Down syndrome

3.1. The pattern of the language deficit

What constitutes the language phenotype of Down syndrome children is a series of selective deficits, from the early stages of their development, to expressive vocabulary, syntax, speech comprehension and speech production, compared to typically developing children, of similar developmental age [4]. However, vocabulary development, as opposed to syntax, is clearly superior to Down syndrome children, as when they are called upon to recognize, identify or produce vocabulary, they perform at almost the same level as children of similar mental age, with or without mental disability. Furthermore, the delay in grammar in relation to vocabulary, which is larger in them than in other populations with intellectual disabilities, increases in parallel with the chronological and mental age and remains in the production and comprehension of syntactic structures, finding that chronological age is important for the development of syntax, while mental age is important for the development of vocabulary. Finally, Down syndrome adolescents perform better in vocabulary comprehension, less in comprehension of syntax, and face difficulty in producing syntax, as reflected in their Mean Length of Utterance (MLU) [14].

3.2. Theories of the language deficit

The language delay in Down syndrome children, usually, coexists with a generalized cognitive retardation and manifests as a linguistic deficiency in expressive or even receptive language, although comprehension skills appear more advanced.

Regarding the factors that slow down their language development, the role of auditory short-term memory is important in the first place, as 60% of these people present mild to moderate hearing loss, which also affects comprehension skills [14].

Another view focuses on the neurological structures, which are subject to language and dysfunction in Down syndrome children, since they have anatomical and neurochemical abnormalities in their brain, which are attributed either to abnormal rates of glucose metabolism in their brain, in areas related to the language function at either slower motor response rates and abnormal cerebral laterality [15]. Additionally, linguistic differences appear to be related to the lack of a dominant language hemisphere, as they do not have the advantage of the right ear, unlike typically developing children, which indicates the existence of a severe disability in language area.

Another possible explanation, for the large variation between their language and cognitive level, is provided by Lenneberg's "Critical Period" hypothesis (1967), which argued that maximum language development takes place before adolescence, while Newport (1982) added that the specific language learning skills are not available beyond the age of 7, according typical language development. Next, Fowler (1984) reported that their language development may be consistent with the general developmental course of maturation, but it will stop or differ from the typical course due to their reduced brain function [4].

An important factor is the quality of the linguistic registration of their environment, as the speech addressed to them consists of short and simple sentences with limited vocabulary, thus not allowing them to acquire the necessary language structures. This, in turn, indicates the reduced maternal expectations for their children's language ability [16], which reproduces the telegraphic speech they receive [17].

The hypothesis that children with intellectual disabilities have reduced motivation in information processing tasks [18], compared to typically developing children of similar mental age, needs further study on the role of motivation or lack of appropriate strategies for their language development [19-20].

Finally, one position that does not receive enough support is the institutionalization of their language, as it is argued that it has a negative effect in many areas of development, including their vocabulary and fluency. However, in a number of syntactic measurements, no significant differences were found with those growing up in a family environment [4].

3.3. Phonology

Down syndrome children have a high rate of phonological errors, similar to those of younger children with typical growth rates. However, the inconsistency of these errors is a special feature of the phonological disorder in Down syndrome. Thus, they use phonological procedures, such as simplifying patterns and systematic sound errors - such as reducing clusters and deleting final consonants - for much longer than their typical peers. Additionally, their poor intelligibility of speech affects the linguistic skill of production and, to a certain extent, it interprets the difference between the level of their receptive and expressive language [21].

3.4. Semantics and expressive language

Although, there is a significant individual variation in the degree of language dysfunction, which depends on the field of language, which is assessed and the age of Down syndrome children, the deficits in semantic processing and especially in their expressive language are greater and even in relation to their general cognitive development [22]. Thus, their expressive language, presents much greater deficits, apparent from childhood, compared to the language of comprehension and non-verbal cognitive ability [23], as evidenced by deficits in phonology and early non-verbal requests, which lead to a slower and limited expressive vocabulary [24], which even in adolescents, rarely exceeds 3-5 years of typical development [25]. In contrast, receptive language and comprehension appear more developed than expressive language, during all age stages until the onset of adolescence [26].

The appearance of the first words and utterances, consisting of two words, takes place at a similar developmental age to the control group, while their verbal vocabulary and especially the expressive one is constantly delayed over time. At the same time, they perform lower in a number of semantic activities such as receptive vocabulary, correlated vocabulary, word-image matching and verbal (expressive) vocabulary due to semantic deficits [22].

Laws (2004) [5] states that individuals, with good phonological memory, imitate and successfully reproduce the syntactic structures of adults and based on these standards have higher performance in expressive language. However, Down syndrome children have a deficit in verbal short-term memory, due to their low level of language skills and not to a specific inherent deficiency in a system of verbal short-term memory. Moreover, their difficulty in verbal versus non-verbal skills is linked to their reduced verbal versus visual-spatial memory function. Furthermore, it has been shown that, in Down syndrome adolescents, comprehension rather than cognitive function or chronological age is a predictor of speech production ability [27].

On the other hand, when evaluated in vocabulary production, using language samples from real communication situations and not from standardized measurements, they show a delay in their expressive vocabulary, in relation to their non-verbal cognitive ability. In particular, their expressive ability is measured by the MLU of their sentences, i.e., by the number of words and / or morphemes they use, in conversation or narrative samples, and this has been found to be less than typically developing children, equated to non-verbal ability [28] or similar developmental age, with other mental health problems. Thus, while Down syndrome children tend to use more complex utterances, with more words, at a similar mental age to their typical peers, the MLU of their verbal phrases increases more slowly, despite its direct relationship to chronological age, resulting in deficits in measurements of syntactic complexity, word frequency, diversity of a fixed number of utterances and word production rate, in language samples of narration and conversation [29]. However, some Down syndrome adolescents show a modest syntactic development in late adolescence, indicating that the development of expressive language, as reflected in the MLU of verbal phrases, in sample narratives - longer phrases, vocabulary diversity - continues into the years of adolescence, at a fairly high rate in the development of expressive language, contrary to the "critical period" hypothesis [30].

3.5. Vocabulary

A high percentage of Down syndrome children (80%) start talking in the 2nd year of their life and only a small percentage (10%) in the 1st year. So, some of them will say their first words, at about the same mental age with children growing at a typical pace and specifically at 8-45 months. However, quite often they do not acquire words until the 2nd year, nor the skill of combining them until the 3rd or 4th year of their age, while they inconsistently use the newly acquired vocabulary, sticking to what characterizes much younger children [31]. Therefore, they produce their first words, usually at a much older age than typically developed children [32], with an average of 21 months and then, their progress slows down, compared to the typical sequence [24]. On the other hand, the deficits of their productive vocabulary -although with significant individual variations- are due to their hearing condition (8%), chronological age (35%) and their non-verbal cognitive ability (13%) [29], while there is more variation between typical and non-typical children in the developmental sequence to acquire their first 50 words. It is also interesting that they find it difficult to understand words that express emotions, due to their difficulty in assessing the perspective of other people in general. In typically developed children, the first words of internal situations start from the 2nd year and after the 3rd year, show a large increase. Down syndrome children will follow the same path, but due to the general deficits in their expressive language, they produce a more limited vocabulary [33]. In addition, they use, to the same extent as their typical peers, words to express physiological states and sensory perceptions and much less words that refer to their will or cognitive ability, because they are unable to understand abstract thinking.

However, in late childhood and adolescence, vocabulary comprehension is an area of potential for Down syndrome adolescents that is compatible with or higher than their nonverbal cognitive ability, unlike other areas of language, such as syntax. Thus, older Down syndrome children and adolescents show typical or accelerated vocabulary development, compared with normal developing children of appropriate developmental age due to intervention programs, which they have accepted to enrich their vocabulary or to the richest, stimuli, learning environment, due to their vocational training [14]. Additionally, they understand better high-frequency vocabulary with specific content, rather than the unusual and conceptually complex vocabulary. Therefore, they need more contact with a word to understand its meaning and benefit from their experience with familiar words, compared to younger children of typical development [2].

3.6. Syntax

In contrast to the development of their vocabulary, the development of syntax is disproportionately delayed and mainly in the production of language, in relation to their non-verbal cognitive ability. In particular, comprehension of the structure is characterized by developmental retardation in late adolescence and early adulthood, which may result mainly from a lack of articular loop exercise, which increases in parallel with the age and it is associated with impairments in their expressive language. Consequently, the gap between vocabulary comprehension and syntax skills increases with chronological age, while still being associated with mean mental age and inadequate auditory short-term memory, which impedes syntactic learning, because it does not allow them to retain memory and process large word sequences. Thus, compared to typically evolving children of developmental age, they have a more homogeneous pattern of syntactic use with shorter and simpler syntactic structures in their oral speech, as reflected in the MLU of their utterances and the omission of grammatical functional words and forms -as they lag behind in grammar morphology skills- [21] minimizing the risk of making grammatical errors through the use of new syntactic structures [28]. Particularly, a comparison of the language structure of Down syndrome children, mild to moderate retarded, with children of typical developmental stage, shows that they initially use two-word formation, in which they encode the same thematic concepts. In the next language stage, children with the syndrome use more words that indicate place and condition, while they find it difficult, similarly to the control group, to form hypothetical sentences and refer to past or future events [4]. At the same time, the beginning of the combination of the two words appears between the 1st and the 6th year, while the formation of the first sentences from the 1st-17th year of their age, producing simple noun and verb phrases and simple questions and negations, in which grammatical morphemes are omitted and in particular, the tense morphemes [21]. Therefore, syntactic deficiencies and not vocabulary place limitations on the narrative production [3]. However, as they use more complex word combinations, at the same mental age as typical developmental children, they gradually show slower growth rates, complexity and length of utterances and inconsistency even in already acquired grammars, indicating that they will never reach a complete knowledge of syntax.

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In the past, their difficulty in achieving more complex morphological and syntactic development was attributed to chronological age, referring to "a critical period" defined by the onset of adolescence, with alternating language stages of "fast growth" and "plateau", when development it slowed down or stopped altogether and was limited to the simple syntax ceiling [4]. However, more recently, it has been found that older Down syndrome adolescents (16-20 years old) showed an improvement in their narrative language, compared to younger adolescents, using complex utterances, similar to those of a typical preschool child matched to MLU [24]. Furthermore, it has been found that the occurrence of delay in their syntactic development depends, in part, on the nature of the sample examined. On the other hand, the fact that utterance length continues to develop, in some adolescents, until the age of 20, does not imply syntactic development, as longer sentences result from the improvement of all language skills, lexical, morphological and syntactic. It was also found that the MLU, in the context of narration and conversation, increases in parallel with the age and mainly in narration, after the age of 16 years. Thus, it seems that the narrative production, which is closely related to expressive language and syntax, is influenced to a lesser extent. Therefore, it seems that the developmental sequence in these children with atypical development is similar to that of children of typical development, compared to MLU, but the syntax develops more slowly than the vocabulary and this deviation widens over time. Otherwise, in terms of comprehension of syntax, the MLU and complexity of syntax continue to increase until late adolescence and early adulthood, rejecting the claim that Down syndrome adolescents have entered the stage of a plateau in syntax or remain at the ceiling of simple syntax and at the same time, making expressive syntax a fertile field of intervention [26]. However, even when they can produce complex utterances, they tend to shorten their sentences, using a lower percentage of long complex sentences, compared to the control group [30].

3.7. Pragmatics

Down syndrome children display a complex profile with strengths and weaknesses in the pragmatic aspects of language, similar to those seen in younger children with typical developmental interactions with their parents or other adults. Thus, from the pre-linguistic stage of development, they have many difficulties in trying to respond to non-verbal requests and therefore their interlocutors have to use verbal and non-verbal modes of communication [34]. Their potential includes the ability to stay focused on their subject, such as children with normal growth rates, of similar mental age and much more than younger children, matched to MLU. Additionally, they respond to requests for clarification in order to restore communication interruption. Another feature is adequate storytelling, with visual support, as they are able to retrieve more plot elements and references to the subject than normally developing children of a corresponding MLU or expressive language level. Also, by extending the content of their narratives with data from other sources and using a larger number of simpler linguistic utterances, they compensate, to some extent, for their deficits in expressive syntax. On the other hand, some areas of pragmatics may benefit from the intervention, as they, usually, begin issues less frequently, than younger children of a similar developmental level. In addition, they find it difficult to construct utterances, in order to express their intention effectively and yet, they will not be the first to state that they did not understand the message of their interlocutor, during their communication, asking for clarifications or additional information [21]. However, these problems are not due to deficits in vocabulary or syntax, but to the very slow processing of information [35]. Finally, they show a low percentage of verbal obsession, off-topic language, stereotyped language in the conversation, due to the cognitive rigidity [19-

20], and at the same time, impairments in the coherence of the conversation and the ability to use contextual information.

4.Digital Games for Down syndrome children

The incorporation of digital technologies in the education domain is very productive, successful, facilitates and improves the educational procedures via Mobiles [56-65], various ICTs applications [66-102], AI & STEM [103-116], and games [117-122]. Additionally, the combination of ICTs with theories and models of metacognition, mindfulness, meditation and emotional intelligence cultivation [123-141] as well as with environmental factors and nutrition [53-55], accelerates and improves more over the educational practices and results. More specifically, games are an important means for children to get to know themselves and their environment, but also for the development of their socialization [36].

Digital games, beyond their entertainment role, can often be used as important intervention tools for SEN children, providing them with equal educational opportunities [37] and access to the job market, more opportunities for independent living and active participation in the community [38].

DS children are familiar with technology and already from the age of 6, on average, they enjoy interacting with digital devices, surfing the Internet and engaging in the experience of digital/video games [39].

However, their mild to severe intellectual disability, social immaturity, and difficulty in developing strategy and generalization have been found to negatively impact their physical functions, such as audio-visual skills, coordination, and balance, that are necessary for gaming. Moreover, they show learning difficulties, due to the premature and accelerated reduction in plasticity of their brains in the hippocampus region, which hinders the storage and recall of new information and knowledge. Thus, although some Down syndrome children will reach a high level of reading, corresponding to age 17-18 of typical development, most of them will remain at a low level of reading and math skills acquisition, equivalent to age 5-6 years of typically developing children [40].

But the findings, from the researches of Wuang & Su (2012) and Feng, Lazar & Kumin, (2010), showed that the use of digital games - action, adventure, puzzle - in which Down syndrome children show a particular preference, can improve the plasticity of their brain in the hippocampus area, as through the interactions produced, during the gaming, neurological changes are observed, which have a positive effect on their memory and learning. This occurs as in the context of games, mainly action games, they develop motivation, through the ability to understand the delivery and retention of rewards, which activate the hippocampus, improving the plasticity of the brain and the functioning of their memory [40]. Thus, several research groups have created a series of digital educational tools, adapted to the specificities of this population, in order to be useful and effective, as their learning is hindered by a number of restrictive factors. The characteristics they considered were deficits in cognitive functioning, attention and short-term memory, their delayed language development, difficulty in processing information, especially when it comes from different channels, at the same time, and in understanding the meaning of iconic symbols and finally, low levels of motivation and frustration tolerance [39].

Digital games can compensate for many of these challenges in the learning process when they provide the optimal level of challenge and pace, adapting the mastery to the dynamics and needs of this specific population, so that they do not experience recurrent failures and frustration, which reduce their incentives to achieve and their confidence. In this way, they keep the mind engaged, through a sequence of play activities, which allow repetition, attract attention and consolidate learning [7]. In addition, digital games offer them information that is easily remembered, as it is provided through a well-crafted story, that stimulates them emotionally and which they can easily recall to solve similar real-life problems [39].

In fact, many video games are designed to operate in the context of modern experiential/active learning theories, providing immediate feedback and are therapeutic interventions for these children, based on virtual reality, i.e., using interactive simulations, with opportunities for active engagement in learning and practice environments, that appear to be similar to what happens in the real-world [41]. In this light, virtual reality (VR) systems have a beneficial effect on the prevention and rehabilitation of the above problems, while at the same time children are attracted by the possibility to compete, as an avatar, in an exciting and fun virtual environment, thereby acquiring skills that would be difficult to obtain, through their participation in activities of a real environment [42].

For the design of the narrative and educational activities of the games, which are self-learning educational tools, specialists in language deficits and mental disabilities and therapists from special education centers collaborated, to maximize their participation and interest, taking into account that these children need specific support in the educational and learning processes [38, 43].

The main principles followed and are promoting cognitive engagement, which is a prerequisite for learning, are: [44].

- The user interface is simple, friendly and appropriate for their developmental age.
- Instructions are short, precise and easy to understand and provided audibly, as well as visually, due to their auditory deficits, with simple on-screen text and large, legible letters.
- Large images and bright colors are used [38], that support and complement verbal information according to the principles of multimedia learning [39].
- A set of well-defined rules is followed, linked to clear learning objectives, providing the right guidance and optimal support, so that children actively participate and engage their minds in the effort, interacting effectively with the main character, without distracting them from the game’s animations and sound effects [44].
- An analysis of their progress is provided, according to the educational objectives.
- The game is easy to use, adapted to their level of motor functionality and their pace of learning [7].
- It is preceded by an introductory video of the activities, which are integrated into the context of a compelling narrative [39].
- Graded levels of a sequence of activities are structured in small steps in the form of scaffolding, which gradually become more challenging to maintain their interest.
- The game offers the possibility, in a fun way, of repetition to stimulate their skills and retain learning.
- The immediate reward, in line with the behaviorism theory, keeps their motivation undiminished, until the end of the game [45].
- Usually, the game includes a list of positive feedback for each successful attempt and words of encouragement, when there is a mistake or failure, as they are very sensitive to negative comments.
- Enough options are provided, so that the player has the possibility to use their knowledge in the activities, within a framework with many support opportunities [38].
- The virtual characters, who guide the users, are individuals with Down syndrome, in order to create an atmosphere of familiarity, trust and identification with the players [9].

4.1. Video games for improving language skills

A. Down syndrome children present with prosody disorder, resulting in unintelligible speech that affects different areas of their language development, such as phonology, semantics, syntax and pragmatics. The consequence of these deficits is to make it difficult to communicate, to experience insecurity and social isolation, hindering their development at a personal and social level.

For this reason, the virtual reality video game "PRADIA: Mystery in the city" was developed, where players (on average from the age of 16) take on the role of the central character in an exploration and problem-solving adventure. Some of the activities relate to improving the perception of prosody in specific contexts, vocabulary and semantics, while others emphasize the production of verbal language and improving their speech, focusing on intonation, syllables and expressing emotions. The game, which requires the continuous presence of a therapist, evolves as the player interacts, with his/her voice, with the other characters of the game and demonstrates satisfactory behavior in a variety of communication situations, where prosodic features are considered very important. Therefore, this video game aims, through prosody comprehension and prosodic expression activities, to improve the learner's ability to communicate effectively in various everyday real-life situations. In addition, it has a system for recording and storing information, related to the interactions of the players and the possibility of audio recording a part of their speech, which can be used appropriately for their speech-language therapy and the comparative study of the high heterogeneity of this population [43, 46].

B. The above educational goals are also served by the design of another interactive video game of exploration and problem solving in the virtual reality world, "Magic Stone", which is a kind of graphical adventure and involves the player's conversations with other characters and navigation through various scenes. Players, interacting with game elements, through the use of the mouse, are challenged to respond to prosody-enhancing activities and language-related puzzle-solving activities, with the help of an instructor. Perception activities focus on distinguishing meanings that cannot be rendered by lexical and grammatical elements, while production activities focus on acquiring the correct pronunciation of sentences. Its innovation is that it incorporates prosody production and comprehension activities combined with reading-aloud, imitation, and speech intelligibility strategies.

The learning objectives of the game are i. to distinguish the different types of sentences ii. to choose the right type of sentences, depending on the particular communication situation iii. to associate different sentence types with corresponding prosodic patterns iv. to produce sentences maintaining the rhythm of utterance, according to the position and duration of pauses and the form of intonation, controlling the volume of their voice. Finally, the video game stores the interaction history and recordings of production activities, which are used as above [39, 40].

C. To learn Sign Language, as an alternative way of communication for Down syndrome children, due to the many problems they face in their speech, an educational software has been designed, which is available for mobile devices and computers and consists of 3 games.

The first game introduces the North Macedonian alphabet and the corresponding Sign Language, and there are letter matching activities and memory games with graded levels. In the other two games, Sign Language symbols are presented through a 3D avatar display and players are asked to match a picture with the corresponding symbol, aiming to learn high-frequency words and phrases or even, to combine words into simple sentences [47].

D. Down syndrome children's learning to read alphabetically requires phonological awareness and letter knowledge. For this reason, a game was designed by "Centro Differencas" in collaboration with the New University of Lisbon, which includes 7 mini-games, in order to provide them with an effective personalized learning, to improve speech and reading skills.

In the "Palavra-a Palavra" and "Fraseando" games, a word or phrase is repeated with the visual support of corresponding pictures, which enhance the child's understanding and ability to recall the information. In the next two games, "Palavras a Rimar" and "Sons Iniciais", many images appear on the player, from which one is the reference image and the others are the possible choices. Thus, in "Palavras a Rimar" s/he is asked to identify and choose the rhyming pictures, while in "Sons Iniciais" s/he is asked to identify the pictures containing words, that start with the same sound. In "Cantar as Palavras" and "Cantar os Bocadinhis" games, the words are divided, respectively, into phonemes or syllables, which the player must correctly count, in order to move forward in the following image. In the latest game "Guardar os Sons", the child learns to associate phonemes with the corresponding graphs [48].

4.2. Video games to enhance literacy, cognitive and fine motor skills

A. To stimulate the cognitive and motor functionality of Down syndrome children, with mild to severe mental disabilities, an interactive video game was developed, consisting of 3 mini-games, each with different levels of difficulty. The system includes 2 types of users: i. the child, who selects the suggested games and ii. the supervisor (or the parent, if the training takes place at home). All 3 games are instantly rewarded with stars and the sound of a voice, while the system records his/her score, allowing them to track his/her progress.

In "Smart Shapes Game", the child must distinguish and match shapes and colors by moving his/her hands, while each successful attempt is accompanied by a sound reference to the name of the color. His/her mobility is stimulated by "Candy Ninja Game", where s/he moves his/her limbs to grab the candies displayed by the game. Upper limb motor skills are mainly developed in the "Collect Coins Game", as s/he turns his/her body left and right to collect the coins that are distributed on the street. The game uses Avatar Kinect, which simulates the child's movement, starting from mild aerobic activities, to enjoyable strength activities, which become, progressively, more challenging, as the child gets stronger [45].

B. The gesture-based video game "BeeSmart" is designed to improve hand-eye coordination, which affects activities of daily living and contributes to the acquisition of preliteracy skills (forming the qualitative characteristics of their writing and learning to read). It was developed based on the Troncoso Down syndrome children's literacy development method (where they learn to read, recognizing the whole word, through the association of written symbols with the corresponding pictograms) and gamification techniques.

The story of the game is presented with an animated video, in which a bee asks for their help to learn new words. Players must identify written words and their corresponding pictorial representation, using the index finger of their right or left hand.

The game includes 4 levels: L1. trace the pictorial representation, L2. trace the written word, L3. order the syllables of the written word and L4. order the letters of the written word. At all levels, visual images appear on the screen and sound the pictorial representation, the written word and its pronunciation, as the child connects dotted lines to draw the pictograph or word. The game is coordinated by a therapist, who adapts the activities based on the player's abilities, suggesting more complex pictograms for Down syndrome children with more developed cognitive skills, and monitors their progress from the file maintained in their profile.

The experience of the participants was exciting and an increase in verbal interaction was observed in children who previously used only Sign Language [10, 49].

C. The "JECRIPE" virtual reality game, consisting of 3 mini-games, which are independent of each other, was developed in Brazil, to enhance the cognitive functionality of preschool children, i.e., short-term memory, perception, imitation, fine motor, eye-hand coordination, receptive and expressive language of verbal language.

The main character is Betinho, a Down syndrome boy, who by interacting with the JECRIPE player, who identifies with him, actively contributes to the improvement of his cognitive, pre-linguistic and linguistic skills, promoting his/her communication capacity and improving the quality of his/her life.

In the virtual environment of the game "The Music House", the child imitates simple body movements, under the music of interactive songs, improving fine motor skills and the ability of eye-hand coordination, while the visual and sound stimuli enhance his/her perceptual abilities.In the scenario of "The Bubble House", by moving the mouse to perform activities of selecting and organizing visual and auditory stimuli, the perceptual ability, the speed and the sensory discrimination is enhanced.

At "The Day Care Center", fine motor skills, eye-hand coordination, perceptive and expressive verbal language are reinforced, through the non-verbal requests of a Down syndrome baby, who indicates to the player, with the movements of the body, some items, which the baby wishes. The child, by clicking with the mouse, selects the correct object and holding down the mouse cursor, drags it near the baby [6, 36, 37, 40].

4.3. Video games to stimulate sensorimotor functionality

The delayed and slow development of the sensorimotor functionality of Down syndrome children makes it difficult to organize and execute a sequence of movements to complete a goal, based on verbal instructions, hindering their consistency in school activities and academic tasks. However, it is an interesting finding that "Nintendo Wii' games provide an effective intervention for sensorimotor development and facilitating brain plasticity of school-aged Down syndrome children (7-12 years), through repeated intensive training and practice, offering the possibility of representation on the screen and observation of task specific activities, performed by the player.

Using 3D technology, "Nintendo Wii" virtual reality video games offer them a computer simulation and feedback environment to track their movements in near real time, as they interact with the games. An avatar that represents the child´'s movement gives the possibility of adjustments, self-observation and self-evaluation of their performance, so that they can continue their training. Thus, after the child completes a sequence of activities, having acquired internal motivation, s/he is in the position to understand the results of his/her movements, predict situations, at a next level of increased difficulty and plan alternative strategies to overcome challenges.

One of these games is Wii Sports, which lasts 60 minutes and consists of a series of small interdependent steps that are structured progressively to lead to the goals. Participating in targeted but also pleasurable activities, children improve limb control and coordination with vision, further stimulating their sensorimotor skills [40, 50].

On the other hand, the early participation of Down syndrome children in physical activities can improve their muscle control, awareness of the body in space, balance, body posture and their increased body weight, with related health problems and ensure them an independent adult life.

This possibility is provided by the systematic use of interactive “Nintendo Wii” games, with the participation of family members, which incorporate virtual reality systems, by playing video games, such as “Wii Sports”, which require physical activity, in which high percentages of energy are spent, which they are equivalent to moderate intensity walking in the same time.

In addition, their participation in physical activities, with other people, contributes to their emotional and social maturation, as they experience the feeling of acceptance, acquire friendships and develop participation skills in games, such as joint strategy skills, waiting for their turn, supportive behavior towards the teammate, compliance with rules and competitive mood. Furthermore, it was found that Wii games, by providing visual, auditory and tactile feedback, stimulate Down syndrome children’s enthusiasm and intrinsic motivation, with their active participation in fun physical activities that they would not be able to experience due to increasing limitations in their motor functionality [42].

Indeed, Rahman & Rahman (2010), in their study with Down syndrome children, aged 10-13 years, observed that when they were interacting with 3 “Wii-Fit” virtual reality video games, over a period of 6 weeks, they showed higher rates of improvement in balance, stability, body posture and agility, compared to the control group, that followed a traditional physical therapy program [40,41].

4.4. Digital games for the acquisition of math skills

A. The organization “Proyecto Dane”, in Latin America, developed a mobile application, “PcSD”, in the context of an inclusive education aimed at developing Down syndrome children’s mathematical skills. It is a virtual reality video game with the SCRUM methodology, which provides the possibility of continuous player participation.

It consists of 7 modules, that require the player to practice their mathematical skills, in order to solve daily and professional life problems. The child has the role of a salesperson, in a clothing store of a shopping mall, which was chosen as the simulation environment of the game, because s/he is familiar with the situations presented in it. In the various sections, his/her preparation to arrive at the marketplace and his/her activities during the practice of his/her job are presented. The game does not require the help of another person, while its fun activities suggest that the player is forced to make decisions, in order to continue the game [38].

B. In the last decade, higher expectations are expressed for the mathematical learning of Down syndrome children, through the approach of the multimedia presentation of the material. Moreover, some researchers, questioning the effectiveness of previous practices for acquiring mathematical skills, through counting coins, identifying numbers and learning arithmetic procedures (addition-subtraction), sought alternative approaches.

Thus, to support Down syndrome children’s numerical awareness, a tablet application was created, based on the representation of the concept of quantity (more-less), which is a prerequisite for understanding the concept of size. They, also, took into account that the early visual representation skills of quantities are a foundation for the gradual learning of mathematics. The level of difficulty was determined by the ratio (not by the absolute number), while the starting point of the ratio is 1:2, where activities are understandable to all children, to finally reach, through small steps of increasing difficulty, to the ratio1:4.

It includes 2 games, played either by the player alone or with the help of the parent or instructor: i. an iPad game, where the player offers to help an indomitable space explorer, Millie, as she constantly faces obstacles, on her way between the planets. The player’s increasing cognitive effort is reflected in increasing complexity and obstacles in the explorer’s path between planets, that require sustained attention and higher levels of persistence and effort. ii.

a card game, which presents pairs of cards, with random arrangement of dots that are representing different amounts. Each pair contains dots of the same shape and color, in different proportions, and the player is asked to choose the card that shows the "most".

This tool was initially used in a 3-cycle study, with Down syndrome children aged 3.5 to 19 years and it was found that they showed high variation in the discrimination of analogies, while in the card game they had higher performances, due to the visual support with specific icons. Moreover, it appeared that they developed response strategies, depending on the level of difficulty, in order to overcome the difficulties [44].

In a subsequent study, with the same bespoke math tool and the participation of children aged 9-14, new versions of the previous games were presented.

In this version i. the first game is "Anna's Robot" and the player helps a scientist to make up the pieces of a robot in his lab, by moving 2 dice, that show random ratios of dots ii. in the card game, the child selects, from the pairs of cards, the one with the most spots iii. a board game was added that included some aspects of the digital game, through non-digital activities, to extend learning in different contexts, under the view that different learning contexts provide different possibilities (more controlled learning situation). In this game, the player must choose between 2 clusters of counters that are in different proportions. iv. digital supplements: it added a second player to Anna's Robot game that enhanced the child's attention and motivation, prompting him/her to develop a strategy to lead the opponent to failure.

Additionally, two more alternative versions of the first game were presented, the Millie Moreorless game, which contained more variation in proportions, and a final version of the original game, which asked children for the choice of "less".

High variability and uneven progression of participants was observed. Engagement with the digital game resulted in improved performance in the non-digital game for all children. Finally, the 2-player version of "Anna's Robot" game showed increased levels of engagement and higher performance, albeit with variations [7].

4.5. Video games to support emotional awareness

Lack of awareness of their own and others' emotions, often, leads Down syndrome children to inappropriate behaviors and experiencing intense emotions, with harmful consequences for their physical and mental health.

Thus, the "Emotion 4Down" video game was designed, consisting of 7 emotions - happiness, sadness, anger, boredom, fear, fatigue, pain - and each of them is developed through 6 activities. The therapist has the possibility, from the menu, to apply personalized parameters, according to the specific characteristics and preferences of the player.

The child starts the game by choosing an emotion and is provided with emotion identifiers and its explanation in different contexts. Then, s/he is asked to choose the emotion presented from 3 different options and to imitate that specific emotion, through his/her facial expressions, by seeing him/herself on the screen. Finally, a photo with the above image is stored in the player's album, who must create the specific emotion by dragging, to a specified area of the screen, the eyes, eyebrows and mouth projected on the screen.

To generalize developing emotions, they are projected to players through animated characters, real people and photographs of the video game players themselves [8, 51].

4.6. Digital games for acquiring basic internet skills

"Web Fun Central" is an interactive digital tool, with rich graphics, animations and sound, that consists of 3 educational modules with corresponding games, although the user can choose the games directly. Designed by the research team AKA New Media Inc., with the intention of the player being, as much as possible, self-directed, guided by a character that encourages and rewards him/her.

In "The Globe Trotter Game", the player practices the internet skills, s/he has just acquired, in the previous educational modules and is based on the idea that the internet consists of Webs that s/he must explore, in order to find interesting information about them.

In "Wacky Pack", which is the next game, the player, using the menu, helps a set of characters on their journey to various exotic locations.

Finally, in the "Party planner" game, s/he enjoys a bus ride that makes a lot of stops. At the end of the route, s/he arrives at a party, but s/he has to return to previous stops, in order to pick up various items for the party.

Within a safe learning environment, which offers quality entertainment, Down syndrome children are taught and practice basic communication and life skills, maximizing the prospects of personal and social development [9, 40].

5. Discussion & Conclusions

Language development is the area of Down syndrome children that presents the greatest impairment, which is exacerbated over time, with the main feature of inconsistencies in the development of different language areas and processes and with higher performance in language comprehension and greater difficulty in the syntax production. At the same time, the cumulative effect of a set of factors - cognitive, linguistic and maturation - contributes to the manifestation of individual differences, displaying different linguistic patterns of strengths and weaknesses, given that children's growth and development is not the same in any person. Moreover, despite their observed delayed onset, their linguistic structures follow the typical order of occurrence, but at a progressively slowing pace - possibly due to their cognitive deficits - starting from the early years of their life and performing at the lowest level of formal variation. These findings, for slow but typical development, are reinforced by the Developmental Approach, which points out that all children cross similar developmental sequences (Hypothesis of the Same Developmental Sequence) and much more from an enlarged developmental perspective, that even individuals with organic etiology mental disabilities, such as Down syndrome children, follow the established principles of development and maturation, but at different rates (Different Rate Assumption) and with a lower final achievement level.

Therefore, all this is in line with what our research has shown, as the language development of Down syndrome children -mainly with mild retardation- was found to be qualitatively similar to younger children of typical development, equated to mental age (cognitive-developmental level). That confirms Lenneberg's (1967) view that "language development, in Down syndrome children, is a slow-moving copy of typical acquisition, similar in all respects, which differs only at the rate of acquisition" [4]. However, in information processing tasks, they differ qualitatively from the formally developing children, as these reflect the pace of cognitive achievement. Nevertheless, according to the hypothesis of "the physical variation" of the developmental model, some forms of intellectual disability are part of the individual variation of typical cognitive development. This finding is consistent with Fischer's words (1980), as saying that "dissimilarity is the rule of development" [52].

On the other hand, given the great heterogeneity of the Down syndrome population, more in-depth research is required of their cognitive and language skills, but also of the results of the provided education, based on the differentiated diagnosis of their linguistic profile. In addition, these findings suggest that, in order for early intervention language programs for

Down syndrome children to be effective, they need to integrate the developmental sequence applicable to children with formal language acquisition, due to the similar trajectory in language acquisition. Furthermore, these programs, taking into account the high variability in their cognitive and language skills, should integrate educational digital/video games that, with the appropriate software and suitable learning theories, can become alternative educational tools for early intervention and effective rehabilitation, enhancing their cognitive, mobile and learning skills and abilities, facilitating their inclusion to formal education and their effective integration into the community.

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