A new decade for social changes
Language Development and Mobile Apps for Down Syndrome Children

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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 mobile apps can significantly improve their cognitive functioning, in order to acquire academic and social skills that will ensure them an independent and quality life.

Keywords. Down syndrome, language phenotype, factors, m-learning, mobile apps

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 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.

On the other hand, nowadays, ICTS promotes the development of software for mobile devices, which are innovative tools to create interactive learning environment for Down syndrome children, utilizing their sufficient visual perception and achieving optimal results in different kinds of skills and abilities. Moreover, m-learning is an alternative educational method, with attractive teaching tools, that are necessary for these children, due to their selective deficits in various areas of their development [6]. Thus, they provide them with incentives to actively engage and take initiatives and, at the same time, contribute to increasing their attention span [7].

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. In addition, it examines the effectiveness of learning through mobile applications, when incorporating appropriate and suitable learning theories and facilitating the more personalized learning [8-9], in order to optimize their learning time and cognitive development [6].

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 [10]. 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 [11].

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 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 [12].

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 [12]. 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) [13].

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 [13].

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 [14]. 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 [15], which reproduces the telegraphic speech they receive [16].

The hypothesis that children with intellectual disabilities have reduced motivation in information processing tasks [17], 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 [18–19].

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 [20].

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 [21]. Thus, their expressive language, presents much greater deficits, apparent from childhood, compared to the language of comprehension and non-verbal cognitive ability [22], as evidenced by deficits in phonology and early non-verbal requests, which lead to a slower and limited expressive vocabulary [23], which even in adolescents, rarely exceeds 3-5 years of typical development [24]. In contrast, receptive language and comprehension appear more developed than expressive language, during all age stages until the onset of adolescence [25].

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 [21].

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 [26].

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 [27] 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 [28]. 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 [29].

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 [30]. Therefore, they produce their first words, usually at a much older age than typically developed children [31], with an average of 21 months and then, their progress slows down, compared to the typical sequence [23]. 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%) [28], 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 [32]. In addition, they use, to the same degree with 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 [13]. 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- [20] minimizing the risk of making grammatical errors through the use of new syntactic structures [27]. 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 [20]. 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.

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 [23]. 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 [25]. 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 [29].

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 [33]. 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 [20]. However, these problems are not due to deficits in vocabulary or syntax, but to the very slow processing of information [34]. Finally, they show a low percentage of verbal obsession, off-topic language, stereotyped language in the conversation, due to the cognitive rigidity [18-19], and at the same time, impairments in the coherence of the conversation and the ability to use contextual information.

4. Mobile Apps for Down syndrome children

The incorporation of digital technologies in education domain is very productive, successful, facilitates and improves the educational procedures via Mobiles [46-55], various ICTs applications [56-96], AI & STEM [97-111], and games [112-118]. Additionally the combination of ICTs with theories and models of metacognition, mindfulness, meditation and emotional intelligence cultivation [119-145] as well as with environmental factors and nutrition [42-45], accelerates and improves more over the educational practices and results.
More specifically, in recent years, there has been an increasing interest in portable devices that are mobile intervention and alternative education tools for children with specific educational needs, which reform a stimulus learning environment. These are digital tools that do not require specific technological knowledge and mainly offer personalized learning, without the constraints of place and time. Additionally, they can contribute to the development of literacy and numeracy skills and to the improvement of cognitive ability and social skills, utilizing the theories of constructivism, behaviorism, social and cooperative learning. An important advantage is the interaction of the person with the mobile device and the concentration of the attention, due to the use of multimedia elements -videos, animations, images, sounds- that make them very attractive and appealing [6, 8, 35, 36]. Down syndrome children present neurodevelopmental dysfunctions in language, memory, concentration of attention, temporal sequence, spatial skills, generalization that are reflected in the slow rates of understanding new concepts, complex rules and the steps of a process, while they need immediate reward to continue the effort [37]. However, additionally to cognitive deficits, the dysfunction in fine and gross motor skills hinder the development of mathematical skills, the effective use of which is linked to the demands of everyday life, work and community participation [38]. More specifically, they have difficulties in learning language, but much more in learning and identifying numbers and mathematical concepts, due to impairment in cognitive and executive functions, which implies slow or incorrect use of mathematical algorithms [35]. Moreover, deficits in verbal short-term memory allow them to recall as many as 6 digits, as the typically developing 7-year-olds children [6].

In this direction, in the last decade, mobile applications have been developed as alternative education tools for Down syndrome children, due to their slow learning rates, and address those with mild to moderate intellectual disability [35, 36, 39]. Besides, the Down syndrome children come into contact with smartphones and tablets from their early years of life, as well as all children. [37]. However, although our research focused on individual areas of their language development, most of the applications that have been developed, so far, for these children concern the development of numeracy skills and the strengthening of their short-term memory, while we expect new interactive applications, easy to use and low cost, that will attract their interest and will reduce their weaknesses, more effectively, than traditional educational strategies, increasing them the possibility of inclusion in formal education and their level of autonomy in real life.

1. MathDS is a mobile application with a platform of Android, which is the most popular low-cost operating system for smartphones with a touch screen. It is an important personalized learning tool for Down syndrome children to learn to count and write numbers from 1 to 10. MathDS is a virtual learning environment through mobile devices, at the place and time of their choice [39]. Equally important is that it consists of activities of calculating objects and things from their daily life, so they are led to construct new knowledge based on their experiences and under the guidance of an adult -teacher or parent-, before starting the activities. Moreover, the activities are structured in small steps, including modeling, demonstration and clear explanation of each step of the process, and students are encouraged to learn through their active participation and exploratory disposition [35]. This digital application has been developed in two languages, in Malay as well as in English, providing the possibility of its use by a majority of children and is structured by three main modules:

   a. Learning, where children learn the numbers from 1 to 10, by touching the desired points on the screen and relating the images or pictures they see on it to their everyday life.
   b. Activities, checking the understanding of what they have learned and include 3 sub-activities
of graded difficulty, with the assistance of objects, colors and animations: i) matching, ii) drag-drop and iii) selection.

c. Practice, where they recall what they have learned and are guided to join the dots shown on the screen to form the numbers.

This application has very impressive results, because it manages to achieve the concentration of attention and the attraction of the interest of Down syndrome children and to make knowledge interactive, simpler and easier to gain [35, 39].

2. Scrum is a flexible software development model for organizing work structured in small steps and it includes 2 basic tools: a. a dynamical hierarchical task list of the entire project and b. a subset of tasks that each development team chooses along with the development plan. The mobile application was designed using Balsamiq Wireframe, an interactive graphic design tool for user interfaces or websites and web applications.

Scrum offers a comfortable teamwork environment that is structured in easy-to-understand and well-developed processes and tools, aiming to improve the cognitive and audio-visual skills of Down syndrome children in a pleasant way [36].

3. A holistic educational application, accessed by tablets and smartphones that have software Android OS 2.3+, is addressed to 2 types of users: a. educators and b. learners. It is an intuitive, scalable, dynamic platform, which uses a. speech synthesizers and b. communications between devices via Bluetooth technology and it provides the possibility of verifying the correct order of implementation of a sequence of tasks.

It contributes to the development of the verbal skills of the spoken language through the synthesis a. text to speech and b. speech to text. In addition, it seeks to develop short-term memory through the implementation of work sequences, while with appropriate modifications it can be used for other populations with mental disabilities. The instructor can manage users, add, edit or remove information from each module, create tasks and send them individually to each student or group of students registered on the platform. The results from its use showed a significant individual improvement of Down syndrome children, in various areas of their cognitive functionality [6].

4. LVDS-App (Learning Vowels Down Syndrome Application) is an easy-to-use intuitive application for a mobile device recommended for learning vowels in Down syndrome children, with mild to moderate intellectual disability, aged 7-11 years. Their deficits in short-term memory and abstract thinking are compensated by superior visual perception skills and are utilized in a variety of activities with specific examples, from a virtual teacher. It is a low-cost learning tool through a tablet which uses the Android Operative system and consists of games that attempt to stimulate the learning of vowels in children, through visual and auditory stimuli. The methodology for developing this flexible application is XP (Extreme Programming) which offers feedback, encouragement and communication. There are 3 modules:

a. In the Learning module, the children learn the phoneme and its form and they acquire the ability to recognize it in reference objects, thus transforming the information of the environment and their experiences into useful knowledge that is stored in their memory in a fun and interactive multimedia environment of graphics, images, videos and sounds.

b. In the Practice module, the virtual teacher asks the children to match a phoneme with the appropriate image and provides them with visual and audio feedback accordingly.

c. In the Assessment module, the learning level is assessed and the children receive feedback as above.
In order to use the application, it is necessary to inform the parents about the tasks and to allow their permission. Interaction with this application increases the children’s cognitive and emotional learning motivation and it stimulates their cognitive functions of memory, attention and perception, while their motor skills are strengthened as they are asked to drag their finger to perform the activities [9]

5. Puzzle-type games are among the most popular for the conventional education of Down syndrome children. Thus, an easy-to-use and portable puzzle video game mobile application was developed, using the Android OS 4.3 operating system, the Unity programming language, and Visual Studio code. Blue and orange colors have been chosen for the application, as they attract attention and stimulate the enthusiasm and active participation of children. It includes educational as well as entertainment activities. In the education module, the child can choose between 3 types of games: a card game to enhance short-term memory and hand-eye coordination and two puzzle games of which the first one offers a first contact with the puzzle game, while the second one is more complex and requires more skills for its use [40].

6. An interactive tool that includes educational activities for Down syndrome children, implemented through a mobile phone application, which can interact via Bluetooth technology with a low-cost robot and motivate their interest in performing the activities with the assistance of the robot. It is used by educators to design intervention programs and refers to the following educational areas:

   a. Speech - Language therapy (STL), with various activities that attempt to overcome the anatomical and physical dysfunctions in the areas of the mouth and throat of Down syndrome children that hinder the precision of their movements.
   b. Learning disabilities for Down syndrome children seem to be greater for mathematical concepts and numbers in relation to reading skills and that is why the activities focus on learning numbers and spatial concepts.
   c. Attention and concentration, as their large attention deficits exacerbate difficulties in discrimination skills, therefore include short-term educational games aimed at increasing attention span.
   d. Perception and awareness of the body. Through a variety of activities, their fine and gross motor skills are improved, while their awareness of their body position in space increases significantly.

All the activities are of graded difficulty and they are selected according to the user’s ability level. In addition, it incorporates many functions, aimed at educators for decision-making, monitoring children’s progress and suggestions for exercises and/or activities for the class [7].

7. DCCDS is an intuitive short game, accessible by touching an active icon on the white screen. It consists of realistic images and bright colors and the pace of the game adapts to the child’s ability level. Instructions are simple and even provided in sign language, while a virtual teacher announces the game and provides visual and audio feedback. The app uses App Inventor 2 and has incorporated constructivism theory. Thus, it consists of three units with levels of graded difficulty and aimed at developing memory skills, literacy and basic mathematical concepts. Each unit includes a virtual teacher, but in the memory and literacy unit there are two additional young female teachers, while in the math skills unit there is an additional young male teacher. They present the instructions, the levels of work, the goals of each level, the names of the objects and provide feedback corresponding to the effort at each level. If there are 3 failed attempts the teacher calmly suggests a retry. Upon successful completion of the task, individualized reward is provided. The 3 sections of the game are as follows:
   a. Literacy Skills: This unit starts with the upper case and lower case letters, shown below the
picture that starts with that letter, and for each letter there are 3 different pictures. There are included 3 games, aimed at correctly finding the letters: i) finding the corresponding image with the displayed letter ii) finding the initial letter corresponding to the image presented. and iii) formation of the spelling of a word based on scattered letters that are given among which there are probably letters that do not belong to the word. After the word is spelled correctly, it is spoken by the virtual teacher and presented as an image.

b. Mathematical Skills: Initially, children are taught the shape of two-dimensional shapes, such as the tetragon, rectangle, triangle and circle, as well as three-dimensional ones such as the cylinder, cube and sphere. The next goal is to teach the relationships between shapes, such as bigger-smaller, left-right, inside-outside, etc. Then, follows the teaching of numbers, accompanied by the relationships the same, less and more. Finally, units of measurement such as length, weight, time and coins are taught.

c. Memory: Memory game reinforces literacy and mathematical skills acquired with previous games. It includes 4 subsections: i) pairing of pairs of equal images ii) pairing an initial letter with the corresponding image iii) pairing a written word with the corresponding picture and iv) pairing a number with the corresponding written word. So far, DCCDS is installed on 10 tablets, in a Day Care Center in Skopje, but there is the possibility to adapt it to other languages and be available for more Down Syndrome children. [37].

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” [41].

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 should integrate educational applications for mobile devices that, with the appropriate software and suitable learning theories, can become alternative tools for early and effective intervention, enhancing their cognitive and learning skills and abilities, facilitating their inclusion to formal education and their effective integration into the community.

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References


Stathopoulou et all A. Mobile assessment procedures for mental health and literacy skills in education. International Journal of Interactive Mobile Technologies (iJIM), 12(3), 21-37, 2018,


Drigas, A.S., Vrettaros, J. and Kouremenos, D. (2004a) ‘Teleeducation and e-learning services for teaching English as a second language to deaf people, whose first language is the


[78] Drigas, A.S. E- psychology and the school psychology science. 27th ISPA Colloquium, Athens, 13-17 July 2005


