Technologies for Down Syndrome Persons

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Since the beginning of the 21st century, the lifespan of people born with Down syndrome (DS) has increased. They now outlive their parents and rely on their relatives who usually sacrifice their own families to care for their disabled siblings. To reduce the pressure on families and the wider community, it is crucial to prepare DS people for independent life from early childhood. Emerging technologies can significantly support the process of acquiring the skills that are necessary for solving real-life problems at home and work.

Keywords: assistive technologies ; Down syndrome ; functional skills ; inclusive education ; technology-enhanced learning

1. Introduction

Down syndrome (DS) is among the most complex genetic disorders that occurs in 1 in 1000 to 1100 live births [1]. The life expectancy of these people has considerably increased, starting from 12 years in 1942, through 47 years in 2007, and reaching 60 years in 2020 [2]. In most cases, the care of these individuals is anticipated to be provided by their siblings [3]. To reduce the high stress of caregiving for aged DS people and to lessen the sacrifice of their own private lives, caregivers should prepare DS children for an independent life [4]. Regardless of various initiatives intended to support the gathering of the essential life skills, the impression is that barely one-third of the DS individuals from the US and the Netherlands were living independently by 31 years of age [5]. Personal experience is not so optimistic. Namely, all the children attending the Day care center for DS children researchers collaborate with do not have sufficient life skills for a fully independent life. Their literacy is very low, disabling them from finding necessary information on the internet or traveling alone. Due to the COVID-19 pandemic, they missed almost a year of extracurricular activities in the center which additionally degraded their communication and practical skills.

DS people have delayed physical growth and mild to severe intellectual disability (ID). Their typical mental ability is below 10 years, and severe ID prevails among teenagers compared to younger children [6]. ID symptoms of DS children usually overlap with the symptoms of autism spectrum disorder (ASD), affecting poor expressive language and nonverbal social communication [7]. Language disorder is affected by their physiological difficulties in correctly articulating sounds [8]. Frequently, DS persons experience challenges in their cognitive functioning and they are more likely to develop Alzheimer's disease [9]. Speech unintelligibility decreases their intellectual, developmental, and cognitive abilities, resulting in poor communication [10]. It is additionally worsened due to impaired memory span, affecting their auditory-verbal memory [11]. Due to the lack of cognitive and visuoperceptual memory, combined with the inability to clearly express their needs, DS people sometimes get lost, even when they know the environment well [12]. Their delayed cognitive development affects motor functioning, including fine motor control, which is important when performing daily activities [13]. All these disabilities become more severe among DS adults because their physical health deteriorates faster than healthy people's. According to Picciotti et al. [14], their hearing declines, starting from 42.9% between 20 to 29 years to 90.91% between 50 and 59 years. Ophthalmological problems affect more than 80% of DS people, affecting their visual abilities [15].

2. Variety of Assistive Technologies

Intended to support persons with various disabilities, the assistive technologies for DS students are very variable. The most widely surveyed is AAC. AAC based systems are developed in the projects reported in the papers: [16][17]. They are primarily related to speech and cognitive disabilities. While AAC video visual scene displays are implemented to stimulate communication and participation [17], communication boards and high-tech electronic communication devices are predominantly carried out in educational sessions and environments [16]. Both systems are suitable for adolescents with more severe communication needs.

VR, which can be enhanced by AR, is the main technology deployed to support people with various disabilities, including DS, across their lifespan [16]. The vocal production effect, referring to memory enhancement via vocally produced words

was successfully used for improving long-term verbal memory by presenting familiar and unfamiliar images, familiar words, and short written sentences and saying the words or phrases aloud [18].

Digital assistants are the main technology to support DS people in developing their life plans [19]. Moreover, they can also be used to help them learn basic arithmetic operations through digital boards [20].

Edutainment as an educational form of using video games is presented in the studies: [21][22][23][24][25][26]. The first paper presents a platform for delivering accessible games for enhancing cognitive learning and training [25]. Two valuable video games support eye-hand coordination [26] and speech skills [22]. A small-scale game “Home game” is an augmented table game that can be played with printed cards and by using touchscreen applications [23]. In a contrast to this game for children, serious games for job training also use the edutainment approach [21]. Finally, cognitive computer games were used to improve attention span [24].

Robots, beacons, and authoring systems are examined in the papers: [16][27][28][29][30]. Research related to these technologies starts with an overview of avatars, humanoids, robots, and VR for obtaining life skills [16]. By using a Lego Wedo 2.0 kit, an educational robot motivates DS children to participate and increase their performance, as presented in the paper [29]. Intended for mobile use, Android devices combined with beacon technology assist DS persons complete different orientation tasks [27]. The web platform consisting of games and virtual scenarios that assists DS persons to participate in various daily living leisure activities is introduced in the paper [30]. Accessible wizards that cover several assistive technologies are the main topic of the paper [31]. Further research [28] introduces an authoring tool intended for children with sensory processing disorders and teaches them to recognize coldness, hotness, vibration, and firmness perception, as well as animal sounds.

Challenges and opportunities regarding hands-on experiences with assistive technologies for people with intellectual disabilities are identified in [32]. The authors show that comprehensive and accessible communication channels play a major role while performing experiments through assistive technologies.

3. Variety of Functional Skills

The reviewed papers included in this SLR introduce a variety of learning activities and tasks intended to enable the gaining of the essential functional skills important to capacitate them for an independent life. They all present mutually related groups of experiments. To support training and integration, two labor tasks: photocopying and document archiving were deployed as smartphone applications [33]. VSDs enhanced by ACC were introduced as an intervention to help students with DS complete steps of specific everyday activities, such as packing backpacks with food [17]. Another valuable contribution to gaining functional skills is the Web-based course that helps IDD persons repeat some working activities in horticulture that they previously acquired during practical teaching [34]. They include planting seeds in pots, planting seedlings in pots, watering using a watering can, and weeding the flowerpot. Games were used to strengthen cognitive abilities and fine motor development through images for painting and the work of puzzles [35]. Serious games for the job training cover eight games: apple packaging, hydroponics, cafeteria food distribution, pen assembly, wood work, mail delivery, ATM, and grocery assistant [21]. Digital assistants for developing life plans enabled four small experiments: proposing a question, discussing their own past and present, a quiz, and brainstorming about their future [19]. “Home game”, which consists of several mini games: home presentation, locate the room, place an object, find the wrong object, find the correct sentence, and quizzes, is also a kind of a game that supports the gaining of life skills [23].

Although the number of papers that deal with the essential functional skills and their gaining is smaller compared to the whole list of selected papers, the exhaustive and ambitious approach implemented to create the experiments, and the overall success, shows promise that various assistive technologies can become the driving force to supporting fully independent life, and consequently, to increase the lifespan of DS people.

4. Variety of Inclusiveness Approach

The selected 24 papers propose a wide variety of different inclusiveness approaches, including the augmented tabletop game for children with cognitive disabilities [23], the authoring system for personalized sensory stimulation [28], virtual reality and robots [16], eye-hand coordination and a pre-literacy skills [26] digital whiteboard interface that support DS students learn addition and subtraction [20], beacon technology that supports DS persons on orientation tasks [27], and data-driven wearable smartwatch sensors [36]. These were mainly used in regular schools by children with different disabilities, including Down syndrome, as well as by their mates with no disabilities. Those technologies that were not

tested in inclusive classrooms were part of the technology-enhanced education in special schools for the children with more severe impairments [16].

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