Computer-assisted training programs to enhance adaptive competencies in adolescents with intellectual disabilities. A systematic review

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Abstract—**Intellectual disability (ID) involves deficits in intellectual and adaptive functioning specifically related to conceptual, social, and practical life domains. Computer-assisted training programs have been shown to enhance adaptive competencies of adolescents with ID, thus helping them to better manage their everyday life and to foster their social inclusion and integration. The present work is aimed at reviewing the existing literature on computer-assisted interventions devoted to adolescents with ID highlighting their actual efficacy and strengths. Implications for future research and practice are discussed.**

Index Terms—**Intellectual Disabilities; Adolescents; Computer-Assisted; Training; Adaptive Competencies.**

I. INTRODUCTION

The 5th edition of the *Diagnostic and Statistical Manual of Mental Disorders* [1] defines Intellectual Disability (ID), also known as Intellectual Developmental Disorder (IDD), as a condition with onset during the developmental period, characterized by deficits in intellectual and adaptive functioning specifically related to conceptual, social, and practical life-domains. Intellectual disability is related to sensory impairments [2]. It is worth noting that the outer world is perceived by human beings through sight more than other sensory modalities such as olfaction [3].

Albeit almost totally unexplored until the last century, the use of computer-assisted tools to enhance the education and training of individuals with ID has witnessed an important increase in recent years [4], and has also been suggested to be very important for psychology [5]. For instance, employing the so-called "serious games" – digital games whose main aim is not much to entertain people, but rather to teach them new skills and enhance their already possessed skills – has been proven effective in training individuals with ID [6,7]. Actually, few reviews have been conducted on the use and efficacy of assistive technology as a self-management tool for people with ID [8], and, more generally, on the efficacy of computer-based tools to enhance different skills of individuals with ID in daily living [9], academic knowledge [8], and other important areas of functioning such as communication, employment, and leisure [11]. This paper contributes to the

scientific field of Cognitive InfoCommunications [12,13], which refers to the link between the research fields of infocommunications and cognitive sciences as well as their relationship, whose goal is "to provide a systematic view of how cognitive processes can co-evolve with infocommunications devices" [12]. An infocommunication system generally refers to "any kind of hardware or software component that collects and stores information and allows users to interact with this information" [12]. Therefore, the present study adds to the literature addressing infocommunication systems by investigating how these devices can aid young individuals with ID to acquire new competencies or strengthen those already acquired.

The current systematic review is focused not on mere knowledge acquisition, but rather on behavioral competency enhancement. As opposed to "knowledge," which can be regarded as the result of information acquisition through learning, "competency" refers to the ability of applying and utilizing acquired knowledge to carry out tasks and solve problems in professional, social, and vocational life domains.

II. METHOD

We reviewed the existing literature on computer-assisted interventions devoted to youth with ID, carrying out a systematic search and selecting relevant references in the following databases: PubMed, Scopus, Web of Science, and PsycInfo. Search terms were chosen with the aim of satisfying all dimensions of interest. The keywords we used for our search were the following: (intellectual disabilit*) AND (adolescent*) AND (compentenc*) AND (training OR intervention). On April 6, 2023, a literature search was carried out in order to create a database of scientific articles relevant to the impact of computer-assisted programs used to enhance various competencies in adolescents with ID. Inclusion criteria consisted of selecting experimental studies only, studies involving samples of adolescent population (aged 12 to 18 years) with a diagnosis of ID and without secondary psychic or physical diagnoses. We set a specific temporal boundary to cover the period from 2000 to present. Exclusion criteria involved studies published before 2000, records written in other languages than English, theoretical studies, and studies concerning ID individuals with other concurrent diagnoses (e.g., Autism Spectrum Disorder and Attention-Deficit/Hyperactivity Disorder).

A total of 562 results were found through database search. After removal of duplicates, eligibility criteria were applied. A total of 484 records were screened based on inclusion criteria.

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417 records were excluded in the screening process, which resulted in the retrieval of 67 records. Among the 67 full-texts assessed for eligibility, 52 records did not meet the inclusion criteria, and were thus excluded from the systematic search. Specifically, 28 did not focus on the research question, 3 were not in English, 17 involved samples not including adolescents, and 4 were theoretical (i.e., not experimental). The systematic search finally led to the inclusion of 15 articles. The details of this procedure are illustrated in Figure 1.
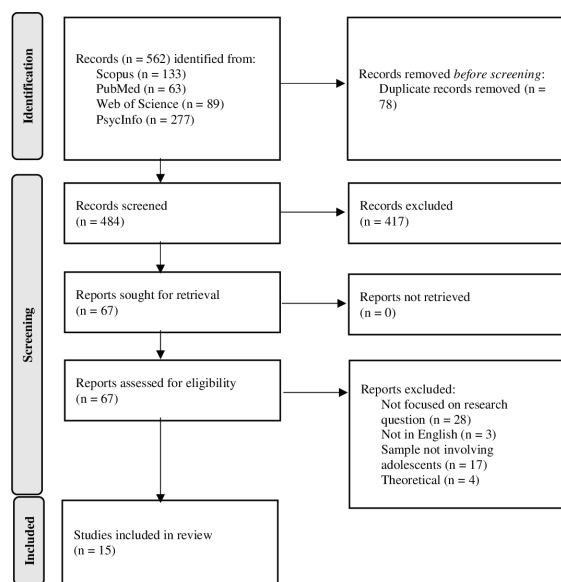

Figure 1. PRISMA 2020 flow diagram

III. RESULTS

The focus, sample, type of study, and results of the 15 included studies are synthesized in Table 1.

TABLE II
FULL TEXT SOURCES RETAINED

Author(s), Year	Sample	Type of study	Results
Bouck et al., 2009	3 individuals with mild ID, 12 y.o.	Multiple probe research design	A pentop computer can be effectively used in teaching multiplication skills to students with mild ID
Cannella-Malone et al., 2012	3 individuals with moderate to severe ID, 15 y.o.	Adapted alternating treatments design within a multiple probe across participants design	Video prompting is effective to teach new skills to individuals with moderate to severe ID
Cihak, Kessler, & Alberto, 2008	4 students with moderate to severe ID, 16-17 y.o.	Multiple probe design across participants	Students with moderate to severe ID can learn to effectively use handheld prompting systems to increase autonomy and independence
Creech-Galloway et al., 2013	4 students with moderate ID, 15-17 y.o.	Multiple probe design across participants	Students with moderate ID are able to learn to use the Pythagorean theorem to solve problems
Gardner & Wolfe, 2015	4 adolescents with mild to moderate developmental disabilities, 13-14 y.o.	Multiple baseline design across participants	Video prompting is effective in teaching individuals with developmental disabilities the skill of washing dishes
Goo, Therrien, & Hua, 2016	4 students with mild to moderate ID, 17-18 y.o.	Multiple probe design across participants	Computer-based video instructional programs alone are effective in facilitating the acquisition and generalization of grocery purchasing skills by individuals with ID
Hammond et al., 2010	3 students with moderate ID, 12-14 y.o.	Combined multiple probes across participants and replicated across tasks	Video modeling is effective in teaching students with ID to independently use iPods
Hansen & Morgan, 2008	3 individuals with ID, 16-17 y.o.	Multiple baseline design across participants	Computer-based instructions are effective in teaching grocery store purchasing skills to individuals with ID
Hudson, 2019	3 subjects with moderate to severe ID, 13-16 y.o.	Single case multiple probe design across participants	iPad-delivered early literacy intervention and self-monitoring can be effective on the acquisition of early literacy skills in some individuals with ID
Kim, Blair, & Lim, 2014	3 subjects with severe ID, 17 y.o.	Multiple probe design across participants	The use of tablet assisted Social Stories™ can decrease disruptive behavior and increase academic engagement in individuals with severe ID

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Mechling, Gast, & Barthold, 2003	3 students with moderate ID, 16-18 y.o.	Multiple probe design across participants	Multimedia programs alone are effective in teaching acquisition and generalization of the use of a debit card to make purchases on an automated payment machine
Palmqvist et al., 2020	38 individuals (IG: N=17; CG N=21). IG: 17.91 y.o. (mean) CG: 7.65 y.o. (mean)	Mixed study (quantitative and qualitative)	A tablet-based program offers a potentially feasible intervention for teaching everyday planning skills to adolescents with ID, who need however more time to get familiarized with the program when compared to typically developing population
Sheriff & Boon, 2014	3 students with mild ID, 13-14 y.o.	Multiple probe single-subject research design	The ability of students with ID to solve word problems using computer-based graphic organizers increase when compared to traditional instructional tools
Taber-Doughty et al., 2011	3 students with mild ID, 12-13 y.o.	Alternating treatment design with a follow-up and withdrawal probe	Video prompting and video modeling are effective in teaching cooking skills to students with mild ID
Van der Molen et al., 2010	95 subjects with mild to moderate ID (IG$_1$: adaptive training, N=41; IG$_2$: non-adaptive training, N=27; CG: N=27), 13-16 y.o.	Randomized, single-blind controlled trial	Working memory can be successfully trained in adolescents with mild to borderline ID

ID=intellectual disabilities; IG=intervention group;
CG=control group; y.o.=years old

The findings of the included articles point to the efficacy of video-based assistive tools in training various skills to youth with ID. For instance, Gardner & Wolfe [14] analyzed the effectiveness of a video modeling procedure on the ability that adolescents with mild to moderate ID had in acquiring daily living skills. The results showed that using a video prompting with an error correction procedure was effective in teaching these individuals to learn to wash dishes. Among other important daily living skills, the capacity to make purchases in different settings is extremely important for independent functioning of individuals with ID. Since purchasing generally involves complex chains of steps that change according to the setting, Mechling et al. [15] analyzed the effectiveness of a multimedia method comprised of interactive computer program, video captions, and still photographs to teach students with moderate ID to use a debit card and an automated payment machine to make purchases, showing its effectiveness in teaching adolescent individuals with moderate ID to use a debit card to make purchases through an automated payment machine. A multimedia computer-based instructional tool has been utilized also by Hansen and Morgan [16], who evaluated its efficacy in teaching grocery store purchasing skills to high-school students with ID, who were able to enhance their purchasing skills, and to generalize them in different grocery stores in a 30-day follow-up. Similar results have been attained by Goo et al. [17], who evaluated the efficacy of a computer-based video instructional program aimed at teaching grocery purchasing skills to high-school students with moderate ID. The results confirmed that computer-based video instruction alone was effective in allowing adolescent students with ID to acquire and generalize grocery purchasing skills. Overall, these findings point to the importance of using technological devices to help individuals with ID acquire or strengthen commercial competencies, with particular focus on making purchases.

Video modeling has been utilized by Hammond et al. [18] to examine its efficacy on accurate and independent use of an iPod by adolescents with moderate ID. The study aimed at teaching students to watch a movie, listen to music, and look at photos on an iPod. Through video modeling, participants acquired the ability to independently use the iPod, also maintaining most of the acquired skills on follow-up probe trials, confirming the effectiveness of this tool in teaching adolescents with ID to use portable technological devices. Taber-Doughty et al. [19] demonstrated that using video prompting and video modeling is effective in teaching individuals with mild ID to independently complete novel recipes and improve their accuracy over baseline levels. Cannella-Malone et al. [20] used an iPod Touch to compare the effects of video prompting on the ability of students with moderate to severe ID to acquire daily living skills. Overall, these results also indicated that video prompting is an effective technology for teaching new skills to adolescents with ID.

Palmqvist et al. [21] investigated the feasibility of an everyday planning tablet-based training program for individuals with ID comparing a group of high-school students with mild to moderate ID and a group of typically developing children attending primary school. After matching the two groups on mental age, the study revealed that the group of ID individuals needed to familiarize with the program before being as active as the participants in the control group when using the tablet-based tool. Even though, in the beginning, the

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subjects with ID seemed to use different strategies compared to those of the control group, nonetheless the training program helped a subgroup of them to develop effective strategies and to use them effectively. Ultimately, these results indicated that individuals with ID generally needed more time to learn to use the program, but were still able to learn as much as the subjects of the control group. This also points to the importance to consider the temporal duration of the use of computerized tools when assessing digital support for subjects with ID.

Van der Molen et al. [22] demonstrated that working memory (WM) related skills can be successfully taught to adolescents with mild to borderline ID who attended special education classes through a computer-based training. The researchers witnessed a significant improvement in verbal short-term memory (STM) from pre- to post-testing in the group that received the training, as compared with the control group. The beneficial effects of the program on verbal STM were maintained at follow-up. These results clearly indicated that WM-related competencies can be effectively trained in individuals with ID, indicating that technological devices can aid individuals with ID in strengthening specific cognitive functions such as WM.

Mathematics is widely considered a relevant and critical content domain for education and evaluation of all students, but its mastery can be hard to attain for individuals with ID. Sheriff and Boon [23] examined the effects of computer-assisted graphic organizers, based on a specific digital software, to solve mathematical one-step word problems in targeted individuals with ID. The authors aimed at evaluating the effectiveness of computer-based graphic organizers to help these individuals to solve simple mathematical problems. During the baseline phase, students completed a worksheet consisting of few functional word problems using traditional tools. Subsequently, in the intervention and maintenance phases, students had to complete the word problems using a computer-based graphic organizer. The results indicated that all participants enhanced their ability to solve the word problems using computer-based graphic organizers, as compared to more typical instructional tools. Furthermore, all participants' performance levels, which were acquired in the intervention phase, were retained during the maintenance phase, confirming the effectiveness of using computer-based graphic organizers to enhance the academic performance of students with ID. Bouck et al. [24] examined the effectiveness of a pentop computer in teaching multiplication facts to middle school students with mild ID. The authors assessed the students' learning of different multiplication facts over an intervention period of 2-3 weeks, after which the authors assessed the students' ability to solve multiplication problems without this tool. The authors witnessed an improvement of the percentage of correct math facts completed by all participants, supporting the hypothesis of the efficacy of the use of pentop computers in teaching multiplication skills to students with mild ID. In a similar vein, Creech-Galloway et al. [25] analyzed the effects that a simultaneous prompting procedure had in teaching adolescents

with moderate ID to use the Pythagorean theorem to solve real-life scenarios that were shown on a short video using an i-Pad. The results showed that all participants learned to use and generalize the Pythagorean theorem formula, confirming that students with moderate ID are able to learn how to use the Pythagorean theorem in real-life situations and to apply it to new situations.

Within the field of cognitive infocommunications, the concept of "mathability" refers to a dimension whose purpose is to investigate combinations of artificial and natural cognitive capabilities relevant to mathematics [26]. This notion has been used to refer to devices with high mathematical and logical potential, which can be used in aiding both further development of sciences and everyday education [27]. Notably, the greater is the mathability of the technological device or application, the poorer student's mathematical skills could be [28]. ID persons tend to have lower math-related skills if compared to typically developing individuals. Therefore, these persons might essentially benefit from the aid of the device-based mathability to the aim of solving a vast array of mathematical, calculus-based, and logical problems. Today, however, since uncontrolled computer-based self-education can be risky, especially in adolescents, it is necessary to focus more on abilities of selection and assessment of gathered information alongside reflection on the obtained result [29].

Individuals with ID typically score lower on standardized reading measures when compared to subjects without ID. It has been argued that this might be due to the fact that measures are based on traditional print materials and do not give these individuals the opportunity to access supported electronic texts (eTexts) [30]. Since eTexts are available in different formats, non-readers and especially individuals with ID have nowadays more opportunities to familiarize with the written word. Based on this premise, Douglas et al. [30] evaluated the effects of different types of supports on the reading and listening comprehension of students with moderate ID, finding that two of the specific eText supports considered (i.e., reading the text out loud and graphic organizers) were effective in supporting their text comprehension. Similarly focusing on literacy skills, Hudson [31] evaluated the efficacy of an iPad-delivered early literacy intervention and self-monitoring on the acquisition of early literacy skills in individuals with moderate to severe ID. The results of the study were mixed, thus pointing to the need to deepen this type of research, given that only two of three participants had increasingly higher percentage of independent correct responses after completion of the early literacy skills lessons in their level. Cihak et al. [32] examined the efficacy of using a handheld prompting system in helping students with moderate to severe ID to independently transition between an ordered set of tasks, demonstrating that these individuals could learn to effectively use handheld prompting systems to increase autonomy and independence. Finally, Kim et al. [33] examined the use of tablet assisted Social Stories™ intervention for high-school students with severe ID with behavioral problems that hindered their learning process. The

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results indicated that this type of intervention decreased
maladaptive behaviors and increased academic engagement of
these individuals, who also demonstrated to be able to
generalize these behaviors and maintain them over time.
Overall, autonomy, independence, and self-engagement have
been thus shown to have the potential to be strengthened
through the use of technological devices in individuals with
ID.

IV. Discussion

Even though concerns have been raised as to the relationship
between the use of digital devices and the individual's
development [34], showing for instance how digital media
inhibit self-regulatory private speech in children [35], overall
contemporary technology has been found to significantly
improve the quality of life of individuals with ID, and provide
them with skills that they can utilize for social inclusion. The
use of modern technologies as instructional tools has become
more and more prevalent in both general and special
education. Furthermore, the significance of assisted
technologies has been stressed by a World Health
Organization statement focusing on the use of
infocommunication technologies to facilitate the access to
services for individuals with special needs and to remove the
obstacles they encounter in their social integration [36].
However, existing technological devices only partially meet
the needs of these individuals [37]. In fact, much needs to be
done in order for ID individuals to be provided with
appropriate technology in the special centers they attend [38].
To date, little literature exists as to the benefits of the use of
technological tools to improve ID individuals' skills and
abilities [39]. This paper aimed at filling this gap insofar as
adolescents are concerned, thus focusing the researchers'
attention on the topic and inviting scientists to prompt new
experimental studies, as well as new types of technological
tools to serve ID adolescents' needs and enhance their
competencies in various life domains. Given the current
digitalization of several life activities, we suggest that teaching
methods should also move from traditional modes of
education towards experience-oriented and cooperative
teamwork-based education, which takes into account the
features of the digital generation [40]. Today, augmented
visual tools based on virtual reality are promoting
experience-based learning processes and transforming the
educational methods [41]. Because the learning processes
have become strongly multidisciplinary and the digital space
has replaced the typical educational environment, learning
materials are available in a form that is independent from
space and time [42]. In the CE generation's digital life, a 3D
VR learning environment can have an encouraging effect on
the students' learning processes [43]. However, we did not
focus only on academic skills, but also – and especially – on
competency enhancement of individuals with ID. This paper is
intended to be of great use to all practitioners who deal with
people with ID and their caregivers. Indeed, professionals and
individuals close to these people should become aware of the
power that contemporary technology has on competency
enhancement and behavioral training of this population.

We believe that social integration and acceptance is to be
fostered for individuals with ID and also for all other minority
groups such as ethnic, religious, and social minorities, and
also people who are gender diverse [44,45]. The latter, for
instance, have been shown to encounter societal pressures that
render them more vulnerable to negative health outcomes,
which they need to face by mobilizing effective resilience
factors to protect themselves from social stigma,
discrimination, and victimization [46]. Our society needs to
deeply acquire the capacity to be inclusive of all diversities to
achieve substantial dignity. In other words, only if the
diversity is accepted and achieves actual integration in our
society, the latter can in fact be named as developed and
mature.

V. Recommendations for future research and practice

The most relevant limitation of this review is that the vast
majority of included studies (n = 15) have a very small sample
size and no control group. Even though this makes their results
questionable, we believe that they can nonetheless bring
important and relevant insights into the usefulness of
computerized tools in enhancing competencies in adolescents
affected by ID. Given the small number of articles with
experimental designs focusing on the effects of technology on
cognitive and social competencies of adolescents with ID, our
hope is that the present review will prompt future scholars to
extend and deepen this field of research. Furthermore, ever
new technological devices ought to be set up to help this
population acquire extremely important cognitive and social
competencies to be more independent and better integrated in
society. In fact, computer-assisted programs ought to not only
serve as instructional tools for academic content, but also –
and perhaps more importantly – to provide individuals with ID
with tools that might serve to improve and enhance their
competencies, skills, and abilities in everyday life. Moreover,
as the sample of the existing studies has been very small so far
(see Table 1), an extension of the number of individuals who
take part of similar studies should be considered. Finally, it
appears that the socio-emotional component of everyday
living has been widely underrated, and it is our hope that this
aspect will be also deeply investigated in future researches
[47].

Overall, in order to aid youth with ID in developing relevant
competencies through the use of infocommunication systems
and technological devices in general, more support needs to be
provided, alongside adequate technological tools aimed at this
specific population. The field of education appears as among
the most promising to achieve this goal, given the importance
of the learning process fostered in young individuals through
the educational facilities they attend. Ultimately, competency
enhancement in this population can be fostered through a
responsible use of technological devices, which has the
potential to render them less vulnerable and more autonomous
in their daily life.

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VI. Conclusions

Our systematic review highlighted how various competencies belonging to the social, adaptive, and cognitive domains can be fostered in young individuals with ID through the use of infocommunication systems and technological devices in general. Acquiring relevant life competencies can aid these individuals in achieving more autonomy in their daily life. Technological devices are becoming progressively prevalent in our society, often replacing face-to-face interactions and learning processes. Therefore, competency enhancement of this population through the use of technological devices can be a crucial step for our society to be authentically inclusive of the various types of diversity that are present within it. To this aim, the psychological empowerment of adaptive competencies in individuals with ID seems all the more fundamental today [48].

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