The application of computer assisted technologies (CAT) in the rehabilitation of cognitive functions in psychiatric disorders of childhood and adolescence

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Summary

First applications of computer-assisted technologies (CAT) in the rehabilitation of cognitive deficits, including child and adolescent psychiatric disorders date back to the 80’s last century. Recent developments in computer technologies, wide access to the Internet and vast expansion of electronic devices resulted in dynamic increase in therapeutic software as well as supporting devices. The aim of computer-assisted technologies is the improvement in the comfort and quality of life as well as the rehabilitation of impaired functions. The goal of the article is the presentation of most common computer-assisted technologies used in the therapy of children and adolescents with cognitive deficits as well as the literature review of their effectiveness including the challenges and limitations in regard to the implementation of such interventions.

Key words: computer-assisted technologies, cognitive functions, child and adolescent psychiatric disorders

Introduction

The presence of cognitive deficits of varied intensity is characteristic of psychiatric disorders of childhood and adolescence such as autism spectrum disorders, mental retardation, disorders of attention, learning disorders but also CNS damage related conditions.

Rapid development of computer technologies and wide access to electronic devices resulted in intensification of interdisciplinary research on methods of rehabilitation of

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cognitive deficits observed in neurodevelopmental disorders. The increase in research also stems from wider access to individualized psychotherapeutic interventions.

The models of interventions and related therapies are aimed at the rehabilitation of cognitive functions such as: memory, thinking, attention, concept formation, problem solving skills, inference skills and reactions to emotional stimuli.

One of the most important CAT-based domains of intervention is communication. Mikołajewska and Mikołajewski [1] list potential benefits of communication devices addressed for people with disabilities, seriously ill and aged, dividing them in three groups: health, social and economic.

Cognitive rehabilitation includes many approaches which define both type and underlying assumptions behind specific intervention. Assistive technologies in the form of supportive devices aimed at the improvement of quality of life within the existing deficit are one the most important types of intervention (communication devices or devices which improve computer accessibility such as alternative keyboards) [2].

The separate category of CAT includes applications and devices used as a part of therapeutic process in the rehabilitation of cognitive deficits of different etiology.

**Aim**

The goal of this article is the presentation of possibilities and scopes of computer-assisted technologies in the rehabilitation of cognitive deficits observed in psychiatric disorders of childhood and adolescence. The article also describes Polish contribution to the development of computer-assisted technologies in cognitive disorders.

*Support and cognitive rehabilitation in executive functions, memory and attention disorders*

Computer-assisted technologies are used in memory disorders, especially in the rehabilitation of executive functions and mixed memory disorders related to the integration of executive functions e.g. working memory disorders. Executive functions are defined as cognitive processes engaged in the intentional control of thoughts and actions which serve effective adaptation to ever changing environmental conditions. The tasks are realized as a result of basic cognitive skills integration such as planning, sequencing, prioritizing, tasks switch, auto-observation, problem solving, activity initiation, but also prospective memory defined as the ability of memorizing things still to be done. In a wider understanding, memory processes include attention, including attentional control. Deficits of memory, executive functions and attention are observed in many child and adolescent psychiatric disorders, including attention
deficit/hyperactivity disorder (ADHD), autism spectrum disorders (ASD), learning disabilities and acquired or congenital CNS injuries [3, 4].

Working memory deficit is characteristic of the majority of neurodevelopmental disorders. Working memory is defined as cognitive function which allows the storage of information for the time needed to process this information, whilst simple storage of information within visual or auditory modality is defined as short-term memory or attention capacity. In Baddeley’s multimodal model of working memory [5] the capacity of attention is an integral part of working memory separated from central executive. The results of meta-analysis on working memory in ADHD have confirmed the presence of deficits in this domain [6].

The available supportive technologies developed for patients with deficits of memory and attention serve more as a prosthetics rather than rehabilitation devices and software. An enormous number of time management software such as planners, organizers or calendars is available on the internet. Localization software is available for patients with massive memory disorders which can identify the location of a person and give instructions about actions (e.g. bathroom – wash your hands). An interesting offer for patients with ADHD is WatchMinder® – a supportive and training device in the form of wristwatch which, among many other functions, helps concentrate during pre-defined time intervals by vibrating and reminding about the need to concentrate.

Some studies suggest the possibility of working memory training with designed software. One of the most popular working memory training software is Cogmed Robo-Memo® [7]. The online application consists of 25 sessions, 30 to 45 minutes each and is made up of 13 customized mini-games. The tasks include letter and number reversal and visual-spatial tasks (e.g. dynamic tasks where the user has to identify the primary location of a rotating object) presented within auditory and visual modality. The application is supported by motivational system through access to attractive computer game. The results of studies on the efficacy of the training have revealed its limited impact on core symptoms of ADHD. On the other hand, an improvement was observed in psychomotor speed as well as reading and counting skills [8]. Polish software is also available for the rehabilitation and support of individuals with ADHD (Cognitomniac series – ADHD module) [9]

The use of computer-assisted technologies in autism spectrum disorders

Computer-assisted technologies create great therapeutic opportunities in autism spectrum disorders, due to the specificity of cognitive deficits (theory of mind deficit). A continual and greatest increase in the number of software applications, reflected in the number of scientific publications is noted in this domain. Between last century
seventies and eighties the number of publications ranged from 3 to 10 a year, with 30–40 studies a year published from 2005 [10].

Computer-assisted technologies used in therapy and support of autism spectrum disorders are applied both on commercial and scientific level. Lewandowska et al. [11] list the following categories of applications: communication, social skills and emotional intelligence trainings and applications developing specific skills: mathematical, linguistic and motor skills. As an example authors give www.iautism.info website which includes about 600 supportive applications, out of which only 8 were available in Polish.

Many authors list potential benefits of computer-assisted technologies for patients with ASD, which include: well defined structure, clear formulation of expectations, predictability of action schemas, minimization of distracters and control over associated problems such as overselectivity [12]. Another argument for the use of CAT is the possibility of immediate reinforcement delivery and withdrawal, the collection of data on trainee’s reactions and usefulness in school environment. The main focus of studies on the application of computer-assisted technologies in ASD is on face processing skills, understanding of emotions, theory of mind, and rehabilitation of social skills.

In a very interesting article about the application of robots in neurological rehabilitation Mikołajewska and Mikolajewski [13] have described the possibilities of utilization of robots in the therapy of ASD. The authors have quoted the results of studies confirming that robots can make a good source of social behavior stimulation in ASD and have listed existing therapy supporting machines (e.g. KeepOn and RoboPanda). The authors have stated that therapeutic robots may be an important complement of other forms of therapy.

Rehabilitation of face processing skills, understanding of emotions and theory of mind

Faces form homogenous class of visual stimuli (similar structure: identical group of elements within the same configuration). Holistic perception and decoding process observed in healthy individuals allows reliable face recognition from the group of faces, despite obvious similarities. Individuals with ASD process faces by concentrating on concrete details with no holistic processing of configuration of details (e.g. relationships and connections between elements of faces). The deficit does not imply the total lack of face recognitions and can be observed in more challenging tasks which require identification of emotional meaning to particular elements. Joseph and Tanaka [14] observed that holistic processing in ASD takes place if the critical emotional information is localized around mouth area. Similar results were observed by Hopkins and Basani [15] in a study on children with ASD. What is more, both authors pointed
out to significant problems with face recognition based on photographs of eyes. Face processing deficits are linked to emotion recognition problems [16] which, according to many authors are a reflection of a broader information processing deficit or deficit of identification of relationships, characteristic for ASD [17]. Emotion recognition deficits (own and others’) are pronounced if an emotion requires mentalization skills (ability to identify whether someone is for example sarcastic, jealous or confused). It is acknowledged that face processing and emotion identification deficits are a basis of social problems in ASD thus computer-assisted technologies mainly address these deficit domains.

Let’s Face It (LFI!) is an interactive application designed for the rehabilitation of face processing deficits (mainly omission of eye gaze in the process of information processing), identification of identity [18, 19] as well as deficits of holistic processing [14, 20]. The domains trained by the application include recognition of faces as source of information, identification of facial expression/identity, identification of face in social context. On the other hand, Mind Reading: The Interactive Guide to Emotions™ [21] is software designed for rehabilitation of understanding of emotions. The software uses the library of 400 emotions (presented in the form of photos or short films), training segment (in the form of quiz games which teach how to match face expressions and tone of voice with different emotions) and interactive games (which require skills such as guessing and matching emotions). The results of research on child population are promising and have shown improvement in identification of complex emotional based faces and tone of voice as well as generalization of acquired skills [22]. Another application designed to improve emotion recognition based on faces and evoked by specific situations as well as identification of mental states is Emotion Trainer [12]. Silver and Oakes [12], in their study with a control group, observed that children with ASD trained with the software had shown improvement in the recognition of emotional states. Moore et al. [23] developed rehabilitation software in the form of three dimensional human-like avatar which simulated participation in real life experiences and acting out four different emotions: sadness, anger, happiness and fear. Training participants had to identify emotions presented, attempt to predict them in various situations but also identify situations which could evoke a given emotion. According to the authors, the improvement observed in children with ASD was mainly due to interactive virtual environment.

Attempts are made to develop a tool addressing theory of mind skills. One of the first computer programs to help stimulate theory of mind was developed by Swettenham [24]. The software is based on false beliefs scenarios. The effectiveness of the intervention has not been proved. Charlop-Christy and Daneshvar [25] used video modeling to teach “taking somebody else’s perspective” as an important component
of the ToM. Children participants were trained by watching videos presenting familiar adults who modeled appropriate behavior which took into account the perspective of other person and explained cues which helped them understand the perspective. The method significantly improved ASD children skills in the trained domain.

Social skills development

Social skills and non verbal aspects of communication deficits are observed in all individuals with ASD although their intensity may vary. Most often observed problems include inadequate eye contact, inadequate reaction to and identification of needs of others and inadequate responses to verbal and non-verbal interactions. Therapeutic interventions, including computer aided technologies may directly address the deficits although they mainly reflect ToM problems. Two technological domains are applied in the therapy of social skills in individuals with ASD: virtual reality and video modeling.

Virtual reality defined as three dimensional simulation of real or imaginary world allows the user to interact with others with the use of avatar (computer representation of the self). Churchill and Snowdon [26] have listed five elements of virtual environment which make it potentially useful in the therapy of individuals with ASD: shared context, the awareness of the existence of others, the need to negotiate and maintain communication and access to different “points of view”. In practice the technology allows participation in everyday situations (such as going shopping or spending breaks in school) and multiple practice of social skills in realistic “here and now” format [27]. What is more, training can be organized in safe and controlled conditions which eliminate stressors which may influence learning process and help to avoid negative outcomes resulting from failure [28]. The method also helps to develop the theory of mind by allowing emotional expression and enforcing interpretation of emotions of interlocutors. The effectiveness of interventions based on virtual technology in ASD has been confirmed, for example in the therapy of social problems solving skills [29] or play interactions [30].

The main goal of video modeling-based interventions is to increase the intensity and diversity of social behaviors. Taking into account communication limitations of some patients with ASD visuo-non verbal models of intervention are often used. The majority of studies on video modeling interventions have revealed positive outcomes in learning new and key social skills. Charlop-Christy et al. [31] showed improvement in emotion expression, spontaneous greeting, conversation skills, cooperation-based play maintenance and everyday life skills. Nikopoulos and Keenan [32] described positive outcomes in the initiation of social interactions, decrease of self isolation and associated increase in time spent on shared play. The study made by Sansosti and
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Powell-Smith [33] has shown the effects of newly acquired skills which included toy sharing, greetings and joining play in two week follow up.

The Polish application Mówik [34] with speech synthesis based on the Polish system Ivona for individuals with speech disorders of varied etiology, including autism spectrum disorders, is commercially available. The producer also delivers software for individuals with severe speech disorders – Gadaczek [35] which enables text message recording which, depending of version, can be accompanied by Mówik system symbols.

A nonprofit website developed by an IT engineer – a father of an autistic boy contains a large number of applications aimed at the stimulation of expressive and receptive speech skills, arithmetic, geometry and clock reading [36]. Cognitomniac series [37] also offers stimulation software for children with autism (Cognitomniac series – Autism module).

“Autilius – unearthly support of therapy” is a computer system for the therapy of ASD children which helps develop social attention, imitation, cognitive and social skills and other domains. The project is currently being developed in cooperation with the Department of Psychology of University of Warsaw. The project is financed by The National Centre for Research and Development [38].

*The limitations of computer-assisted technologies in ASD*

According to some authors the application of computer-assisted technologies may increase problems characteristic for ASD [39]. The limitation of interactions with therapeutic and educational environments may lead to even greater social isolation. The “rigidity” observed in some patient with ASD may be reinforced or increased as well as the number of challenging behaviors related to denial of computer access or obsessive compulsive behaviors. A very important question related to the application of both computer-assisted technologies and traditional approaches is generalization of skills acquired by individuals with ASD onto other environments (the improvement is observed and only limited to concrete task activity)

*The application of computer-assisted technologies in learning disorders*

Visuo-spatial, auditory, language and sensory deficits are characteristic of learning disorders and supported by computer aided therapies. In several studies on patients with dyslexia speech identification and dynamic modification of text software was used (e.g. SeeWord®) [40]. In particular, the software addressed difficulties with visual decoding of letters, numbers, punctuation marks or complete words which contained similar shape letters. Supporting software (e.g. Inspiration®) which helps to create
concept maps of a written text (defined as the categorization of information in visual mode) and present written text through auditory modality is also available.

Polish software market offers a wide range of therapeutic software and supporting devices for children with learning disabilities, speech disorders as well as hearing and communication problem (applications: Logopedia 2.0 [41], MatŚwiat, Dysleksja [42], Cognitomnian series – learning disabilities module [43], Eduterapeutica therapeutic software [44]).

The application of computer-assisted technologies in mental retardation

Individuals with mental retardation form a highly heterogeneous group due to etiological complexity and unique clinical presentations. The choice of computer-assisted technologies should remain in close relationship with diagnosed cognitive and communication deficits. The computer-assisted technologies have been developed within early intervention, stimulation of cognitive functions (e.g. Abrakadabra – an application stimulating cause and effect reasoning) as well as stimulation of more complex skills such as reading or writing.

Communication deficits are addressed by VOCA (voice output communication aids) speaking devices (e.g. QuicTalker communicator) [45] and other augmentative and communication technologies (e.g. application Mówik) [34].

Computer-assisted technologies are also used in optimization of activities of daily living (ADL) and increase of independence (e.g. BJ TOYBOX device which enables control over many toys or other devices or Comfy keyboard for easier computer use [46]).

In terms of supporting children with mental retardation software there is available software to support early childhood development. One of the most powerful Polish application is Wczesne Wspomaganie Rozwoju – Z Tosią przez Cztery Pory Roku (Early Development Support – Four Seasons with Tosia) and Tosia i Przyjaciele (Tosia and Friends) [47]. The application, complemented by the application of the therapist, is designed for the early treatment of cognitive, perceptual and motor functions disorders, multi-sensory stimulation and comprehensive child development support.

Recapitulation

The application of computer-assisted technologies in the rehabilitation of cognitive deficits observed in neurodevelopmental disorders is a very promising supplement of traditional therapies due to high customizability and universality. It seems that technology-based intervention may take lead in the therapy of ASD in the future. A lot of studies have confirmed the effectiveness of technology-based interventions
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in neurodevelopmental disorders. Unfortunately, the lack of strictly defined control
conditions and comparisons with evidence-based treatments is a serious limitation of
most of the studies.

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