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New technologies used in the spatial orientation of people with visual impairment

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The fast development of electronic and information technologies makes them becoming ever more present in the lives of the blind and visually impaired people. The aim of this article is to present modes of mobility of people with visual impairment, with particular focus on new technologies. The article contains the classification and characteristics of electronic aids used in spatial orientation and mobility for blind people. It also presents the benefits and difficulties of using these types of new technologies. The article presents research projects related to the construction and testing of new technical solutions in Poland.

KEY WORDS: spatial orientation, visual disability, electronic orientation aids, electronic travel aids, electronic mobility aids

Persons with disabilities of sight come up against a multitude of hindrances in daily life, stemming from the inability to visually receive information. These limitations apply most often to areas such as: communication (acquisition, reception and exchange of oral and written information), spatial orientation, independent mobility, independent execution of daily activities (in particular those that require visual control). The scope of the experienced limitations depends broadly on the level and time of eyesight loss, as well as the course of the rehabilitation process.

The main area subject to disturbances in persons with sight impairments is the ability to find their way around and move independently. The former of these pertains to processes taking part within the human mind, and entails the correct determination of one's own location with respect to other objects around them, while the latter is related to physically moving around[1]. An individual perfects both these abilities in course of own development, almost throughout one's entire life. However, the process of acquisition of the ability to find one's way and move around in persons with eyesight disabilities does not proceed as spontaneously as it occurs for well-sighted persons. It requires a directed, long-term education process[2]. The reinforcement and development of this area is of particular significance, as the ability to find one's way is necessary almost in every area of our functioning: when moving around one's own apartment, when cooking lunch, getting dressed, playing. Spatial orientation is also necessary during various activities related to social life (making social contacts, shopping, learning or working, etc.). Hence, issues in this area may lead to the loss of independence and various limitations of participation by persons with eyesight disability in social, professional and cultural life[3].

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[1] In literature on the education of the blind, one can find many definitions referring to the understanding of the term of spatial orientation. In Polish literature, the broadest, most quoted definition is the one by J. and J. Kwapisz, J. Kuczyńska-Kwapisz, J. Kwapisz, Rehabilitacja osób niewidomych i słabowidzących. Przewodnik metodyczny. Wyd. Interart, Warszawa 1990, p. 5.

[2] A detailed characteristic of the development of abilities in spatial orientation in people with visual impairments over the course of life was included in the chapter: M. Walkiewicz-Krutak, „Od narodzin do dorosłości" – wspomaganie rozwoju umiejętności w zakresie orientacji przestrzennej i samodzielnego poruszania się dzieci i młodych osób niewidomych, [in:] K. Czerwińska, M. Paplińska, M. Walkiewicz-Krutak [ed.], Tyflopedagogika wobec współczesnych przemian przestrzeni edukacyjnej. Wydawnictwo APS, Warszawa 2015, pp. 259-288.

[3] K. Czerwińska, K. Miler-Zdanowska, Teaching model for students with visual impairments. [in:] Education of Students with Special Needs. World Experience.

Free, safe moving around is a challenge for persons with eyesight disabilities. This applies in particular to being able to move around an urbanised environment. In an urban setting, where noted must be the ever-growing increase of traffic volumes, an expanding transport network, and no unified architectural system, persons with sight disabilities experience problems with overcoming the present transport and architectural barriers[4].

When moving around, persons with sight disabilities can make use of several mobility modes. Subject literature indicates four basic methods of moving around: with a well-sighted guide, with a long cane, with a guide dog, with electronic mobility aids[5]. The choice of the mode of movement depends on many factors. The most important of these are: the age, level of eyesight loss, of physical fitness, of cognitive processes; skills relevant to the ability to find one's way around, personal preferences of the person with the sight impairment, knowledge and complexity of the area, etc.[6].

In Poland, persons with sight disabilities, when moving around, most often use the help of a well-sighted guide, and moving around using a long, white cane. These are the oldest, most broadly available, and hence the most practically proven mobility aids for the blind and those with weak eyesight that are best described in literature. The use of a guide dog is becoming ever more popular. This

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Individualized Education and Therapy Programs (IETPs), ed. by E. Kulesza, Wydawnictwo APS, Warszawa 2013, p. 128.

[4] E. M. Guzik-Makaruk, E. Jurgielewicz-Delegacz, Badania nad bezpieczeństwem osób z niepełnosprawnościami, w tym osób niewidomych i słabowidzących, uczestniczących w ruchu drogowym, „Niepełnosprawność – zagadnienia, problemy, rozwiązania". 2016, no. 1, p. 36.

[5] W. H. Jacobson, The Art. And Science of Teaching Orientation and Mobility to Persons with Visual Impairments. AFB Press, New York 2013, p. 3.

[6] A list and classification of factors that influence the teaching of spatial orientation were included in the chapter: K. Miler-Zdanowska, Czynniki warunkujące nauczanie orientacji przestrzennej i samodzielnego poruszania się osób z niepełnosprawnością wzroku, [in:] K. Czerwińska, M. Paplińska, M. Walkiewicz- Krutak, [ed.], Tyflopedagogika wobec współczesnych przemian przestrzeni edukacyjnej. Wydawnictwo APS, Warszawa 2015, pp. 289-306.

form of aid for persons with sight problems during travel has been known for long[7]. However, it was only the emergence of specific legal and financial[8] solutions as well as improved knowledge on guide dogs that caused increased interest in this mode of mobility among persons with sight disabilities. The Polish *Guide Dog Foundation* (Pl. Fundacja Pies Przewodnik) estimates that in Poland about 200 persons with sight disabilities own guide dogs[9]. However, the number of such users in Poland as compared to other European countries remains unsatisfactory.

However, despite the fast development of electronic and computer technologies, moving around using electronic aids remains the least popular. This is most probably due to the insufficient knowledge about such equipment, both among those interested themselves, as well as among the teachers working with persons with visual impairments[10].

Characteristics of electronic tools used for spatial orientation of visually impaired persons

Ever more frequent use of modern technical and computer aids is visible in the lives of persons with sight disabilities. New solu-

[7] The history of training and usage of guide dogs in he context of support of persons with visual impairments was described in detail by M. Garbat, Wsparcie osób z niepełnosprawnością wzroku – krótka historia szkolenia psów przewodników i posługiwania się białą laską, Niepełnosprawność – zagadnienia, problemy, rozwiązania, Wyd. PEFRON, Warszawa 2013, no. III (8), pp. 81-107.

[8] Polish act of law of 21 November 2008 on changes to the act of law on professional and social rehabilitation and the employment of the disabled, the local taxes and fees act and the food and nutrition safety act, Journal of Laws of 2008, no. 223, item 1463.

[9] K. Domańska, Pies przewodnik osoby niewidomej, „Szkoła Specjalna", Wyd. APS, Warszawa 2014, no. 5, p. 345.

[10] E. Śmiechowska-Petrovskij, Kompetencje nauczycieli uczniów niewidomych i słabowidzących w zakresie wspomagających technologii informacyjno-komunikacyjnych, Niepełnosprawność. Dyskursy pedagogiki specjalnej, Wyd. UG, Warszawa 2016, no. 21, pp. 106-119.

tions and equipment are referred to as assistive technologies or aid technologies. These are all kinds of devices, systems, hardware and software that were manufactured for this purpose or which constitute generally-available aids. Their main task is the improvement of the level of functioning of disabled persons. They permit the improvement of simplicity of execution of tasks or raise the safety during its performance, and in certain cases, they constitute the condition of execution of a specific activity in the first place[11]. A specific group among these aid technologies are electronic aids used for spatial orientation and independent movement of blind and visually-impaired persons. In general, one differentiates among them between two basic groups. The first of these includes electronic mobility aid tools, or Electronic Travel Aids, ETA; the second are Electronic Orientation Aids, EOA[12].

Electronic Travel Aids are also referred to as obstacle detectors. These are relatively small devices which, by emitting ultrasounds or light, detect objects within one's transport corridor, warning the user through vibrations or sounds[13]. Thanks to such devices, it is possible for one to move around persons standing on the pavement, parked cars, advertisements, and find a free seat on a bus without the use of tough. Their biggest flaw are limitations in the distance of detection of obstacles along the route(between 0.5 m and 8 m)[14]. In practice, this means belated detection of thin obstacles (e. g. pillars), and premature detection of large surfaces (e. g. cars). A further issue

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[11] Assistive products for persons with disability – Classification and terminology, ISO 9999, 4th ed., 2007, p. 8.

[12] W.R. Wiener, R.L. Welsh, B.B. Blasch [ed.], Foundations of Orientation and Mobility. Second Editions. New York: AFB Press, 1997, pp. 238-259.

[13] F. Farcy, R. Leroux, A. Jucha, R. Damaschini, C. Grégoire, A. Zogaghi, Electronic travel aids and electronic orientation aids for blind people: technical, rehabilitation and everyday life points of view, Conference & Workshop on Assistive Technologies for People with Vision & Hearing Impairments Technology for Inclusion CVHI 2006, pp. 1-12.

[14] L.F. Cuturi, E. Aggius-Vella, C. Campus, A. Parmiggiani, M. Gori, From science to technology: orientation and mobili ty In blind children and adults, Neuroscience and Biobehavioral Reviews, 2016, no. 71, p. 243.

is erroneous use of relevant sound patterns or tactile stimuli recreating the image of one's surroundings. In most cases it entails the wrong adaptation of the volume of the environmental information conveyed to the perceptive abilities of an individual (referring to auditory and tactile perception). Excessive volumes of information on space are conveyed to a blind person[15]. In practice this describes a situation, in which a blind person is unable to move because they are constantly trying to interpret stimuli that is conveyed to it. In many cases, thus there exists the necessity of selection of objects to be detected so that the movement could be effective.

Electronic Travel Aids can be found as stand-alone devices that due to their small size (of a matchbox) can be held in the hand or attached to the white cane. They can be also built into the white cane. They can be seen in the form of glasses or bands put around one's wrist. Many obstacle detectors have been constructed and manufactured (e. g. Miniguide, Minitact, Palmsonar, Ray, Teletact, Tom Pouce, Laser Cane, K-Sonar)[16]. Despite the use of the most modern achievements in engineering, none of the developed devices was commonly accepted by the community of the visually impaired. In view of Mr Rafał Charłampowicz, the cause of this lies in the lack of awareness on the subject of such mobility aids among teachers of spatial orientation, as well as lack of relevant training courses, as well as the difficulty among the visually-impaired to simultaneously acquire various stimuli[17].

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[15] P. Strumiłło, Elektroniczne systemy wspomagające niewidomych w poruszaniu się i nawigacji, Ergonomia niepełnosprawnym w organizacji pracy i zarządzaniu – projektowanie. Łódź 2008, p. 163.

[16] A list of mobility-assistance devices in table form can be found in L.F. Cuturi, E. Aggius-Vella, C. Campus, A. Parmiggiani, M. Gori, From science to technology: orientation and mobility in blind children and adults, Neuroscience and Biobehavioral Reviews, 2016, no. 71, p. 243.

[17] E.M. Guzik-Makaruk [ed.]. Możliwości wykorzystania i wdrożenia nowoczesnych technologii do budowy narzędzi wspomagających codzienne funkcjonowanie osób niewidomych, Wydawnictwo PPBW Sp. z.o.o, Kraków-Białystok-Poznań 2011 (Publication created within the scope of the development project enti-

A second group of electronic devices used for spatial orientation and independent movement of visually-impaired persons is composed of electronic navigation tools. These are various systems based on the Global Positioning System, GPS. Initially, these were special purpose-built devices (e. g. Trekker Breeze, Navigator, NaviEye, etc.). By size and look, they were akin to television remote control units, fitting in the hand without much difficulty[18]. However, as smart phones became more prevalent, and with them the possibility of installation of appropriate navigation software, their usage dropped. The emergence of the iPhone, in turn, caused a unique revolution in the use of navigation applications by visually-disabled persons for the purpose of independent mobility. The applications available on the market all act quite similarly, e. g. they can describe the location, where the user is found, and indicate the direction, in which they should move. A blind person, when moving around, receives auditory information in the form of verbal descriptions, or tactile information in the form of vibrations, and based on these, chooses the direction, the path that they wish to take. The applications available on the market used for navigation can be software available generally for all mobile phone users (e. g. Google Maps), or software dedicated for the blind (e. g. BlindSquare). Doubtless the biggest advantage of navigation applications is their ubiquity and discretion. A blind person uses such a device (a mobile phone) just like a well-sighted person does. This device does not make her stand out from among other users. The biggest flaw remains the low precision of applications, as compared to the expectations of users[19] as well as limited sensitivity of the GPS to signal

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tled „Legal and criminological aspects of the implementation and usage of modern technologies in the service of protection of internal security" no. 0R00003707).

[18] M. Rotnicki, Treeker Breeze – pomocnik w orientacji przestrzennej, Tyfloświat, 2010, no. 3(9), p. 20.

[19] Persons with sight disabilities require, in order to move around independently, beside information on the cardinal directions and distances, detailed information on objects in space (e. g. the arrangement of stops, names of buildings, pedestrian crossings, names of intersections, etc.).

reflections in areas with tall buildings, as well as the inability to use this solution within buildings[20].

Both Electronic Travel Aids as well as Electronic Orientation Aids are being used increasingly often by the visually-impaired. One could basically differentiate between two types of activity, where they are most commonly used. The first of these is route planning, which begins already at home, at the computer, and spans: acquisition of the topography, planning of the route and also getting to know the timetable of the transport resources available at the particular location. The second is already directly related to actually moving around in space, and entails the determination of the cardinal directions, controlling distances, determining the names of streets/ intersections, the names of the nearby orientation points, the locations of buildings, stops, etc. In both cases, the use of electronic tools is very helpful, primarily due to the ease and speed in which information about the surroundings can be obtained. Quite an important advantage of such aids is also their design, both in terms of size as well as aesthetics.

Research on the use of electronic tools in spatial orientation and independent mobility

Issues concerning spatial orientation and independent mobility are the object of interest of various groups of scientists. They are most commonly rooted in the area of special education and psychology. However, the development of technology, computer science, electronics, and the use of new solutions in designing of aids

[20] R. Charłampowicz, Mobilność bez wzroku. Problemy i potrzeby [in:] E.M. Guzik-Makaruk [ed.]. Możliwości wykorzystania i wdrożenia nowoczesnych technologii do budowy narzędzi wspomagających codzienne funkcjonowanie osób niewidomych, Wydawnictwo PPBW Sp. z.o.o, Kraków-Białystok-Poznań 2011 (Publication created within the scope of the development project entitled „Legal and criminological aspects of the implementation and usage of modern technologies in the service of protection of internal security” no. 0R00003707), p. 20.

for persons with sight disabilities had caused this area to be analysed by computer engineering and acoustics scientists.

In Poland, for several years now, attempts have been undertaken to create aid equipment for spatial orientation and independent mobility of blind persons and persons with sight disabilities. In the years 2009-2012 Rafał Kozik, a doctoral graduate of the University of Science and Technology in Bydgoszcz, headed by prof. Ryszard Choraś, implemented the research project *Complex image processing and computer-based vision algorithms for the support of blind persons* („Złożone algorytmy przetwarzania obrazów i komputerowej wizji dla celów wspomagania osób niewidomych")[21]. This project concerned the construction and testing of a device to register objects, identify them and determine their location, and translate the data obtained in this way into verbal information. The main goal is to warn the blind person ahead of collisions with obstacles and to detect hazardous objects. This is made possible by algorithms able to detect objects within images (e. g. mug with warm coffee, pot with boiling water, etc.). A similar project was conducted in the years 2007-2010 by professor Andrzej Materka and his team at the Technical University of Łódź[22]. The scientists had built a device the size of a mobile phone, with head phones, protruding keys and a camera, that permitted remote guidance for a blind person (the camera image is fed live to the guide computer of the blind person). Ten adult blind persons and their families were invited to test the equipment. The users' reviews indicated that the system is very useful for travelling in very crowded places. Presently, the team of scientists of the Technical University of Łódź is working on perfecting the device so that it would not require the aid of third parties

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[21] A detailed description of the project and the constructed device as well as its mode of operation can be found under http://www.kujawsko-pomorskie.pl/index.php?option=com_content&task=view&id=18003&Itemid=533 [accessed on: 20.05.2015].

[22] Information on the project can be found at http://www.naviton.pl/ [accessed on: 21.05.2017] and in the article by P. Strumiłło, Elektroniczne systemy wspomagające niewidomych w poruszaniu się i nawigacji, Ergonomia niepełnosprawnym w organizacji pracy i zarządzaniu – projektowanie. Łódź 2008, pp. 160-169.

when the blind would like to move around. Engineers from the AGH University of Science and Technology of Kraków are presently also working on a „GPS for the blind". The system is supposed to aid moving around streets and detect obstacles. It is composed of three parts. The first is a sensor in the form of an antenna of any length and shape. Its purpose is to register a blind person in its vicinity. The second is a control device transmitting information on the presence of a blind person nearby, and feedback set to cause an appropriate reaction of the system. The third component is a watch-sized wristband. It emits signals permitting the detection of obstacles. On approaches to street crossings, it informs the blind person about this. Work on the system is ongoing[23]. Scientists of the University of Białystok headed by prof. Ewa M. Guzik-Makaruk, as part of the project *Development of a system of detection of safety hazards for blind and visually-impaired persons, with particular consideration for traffic. Legal, criminological and technical aspects* („Opracowanie systemu wykrywania zagrożeń bezpieczeństwa osób niewidomych i słabowidzących ze szczególnym uwzględnieniem ruchu drogowego. Aspekty prawno-kryminologiczne i technologiczne")[24], are designing a device aiding the mobility of blind persons. As part of the research work, designed were: a system analysing the image from cameras worn by the user that recognises key hazards (this can be e. g. approaching the edge of a platform), and informing of the types and numbers of vehicles approaching a stop; a system utilising depth of perception to evaluate the distance between the user and obstacles in the way; satellite navigation; an obstacle detector. All the proposed solutions are important to provide safety and comfort of movement of visually-impaired persons in an urban envi-

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[23] Detailed information on the developed system can be found in I. Trębacz, Uczeni z AGH opracowują GPS dla niewidomych, Biuletyn AGH, 2011, no. 47, pp. 14-15.

[24] E.M. Guzik-Makaruk, E. Jurgielewicz-Delegacz, Badania nad bezpieczeństwem osób z niepełnosprawnościami, w tym osób niewidomych i słabowidzących, uczestniczących w ruchu drogowym, „Niepełnosprawność – zagadnienia, problemy, rozwiązania". 2016, no. 1, pp. 36-41.

ronment. The project is currently undergoing testing. Employees and students of the Technical University of Rzeszów have also made attempts at developing a device to aid the movement of the blind. As a result of the work, a light, GPS-equipped cane was constructed for persons with visual disabilities[25]. The tip of the cane – both the front as well as the sides – are equipped with reflection sensors to scan their vicinity. When a blind person comes close to an obstacle, the device sends out a warning tone. The closer to the obstacle, the higher the tone frequency. The device was praised, and its creator was invited to present their invention at the 45th International Exhibition of Inventions in Geneva.

Summary

Research work on the development and usage of systems aiding independent travel of blind persons have been going on for more than a dozen years now. However, despite the technological advancements in engineering and medicine, the developed systems are still not commonly used by the blind. Many potential users treat them as gadgets, not looking for real aid in them. Inventors and creators in turn see them as a chance to improve their own financial situation. Quite frequently, information on new aids is limited to their technical characteristics, and the constructed hardware does not leave the research facilities. There is no systematic verification of their usability by the visually impaired. And even if a device is to successfully pass laboratory tests and make it to the market, interested beneficiaries are not able to make themselves personally acquainted with the it, try it out before buying it. It needs to be remembered that most aids based on modern technologies do not facilitate spontaneous learning of their use. A blind person needs at times training in this regard, and then training on how to use the

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[25] http://okulistyka.mp.pl/aktualnosci/158694,laska-z-gps-dla-niewidomych [accessed on: 15.05.2017].

aid in daily life. And here is where a further problem arises, spanning the lack of knowledge among specialists working with visually-disabled persons (teachers, specialists in education of the blind, teachers of spatial orientation and independent travel) with respect to the handling and use of such equipment. For this reason as well, they are distrustful of modern solutions and unwilling to implement them.

In many cases, the importance and the abilities of use of the electronic aids for independent travel are overestimated, as it is forgotten that in order to effectively use them, basic skills in spatial orientation are required. Basic training is needed entailing the mastering of the ability to move about with a white cane; the ability to interpret auditory and tactile information from the environment; obtaining knowledge about the structure of the environment, the ability to create a mental map of one's surroundings[26]. Thus, the use of traditional techniques is the basis for use of aid technologies. A further significant factor is the motivation of those learning. A blind person must want to be independent and determined to learn and painstakingly exercise so as to effectively use the new technologies.

Spatial orientation and independent movement by the blind and those with visual impairments may be supported through the implementation of modern tools utilising the newest technological advancements. However, in order for their application to be effective, the fulfilment of the few conditions mentioned above is necessary. It seems, however, that the best solution would be interdisciplinary work of several specialists in the construction and implementation of modern technologies (computer scientists, engineers, psychologists, neurologists, specialists in education of the blind as well as the blind and the visually impaired themselves.

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[26] F. Farcy, R. Leroux, A. Jucha, R. Damaschini, C. Grégoire, A. Zogaghi, Electronic travel aids and electronic orientation aids for blind people: technical, rehabilitation and everyday life points of view, Conference & Workshop on Assistive Technologies for People with Vision & Hearing Impairments Technology for Inclusion CVHI 2006, pp. 6-7.

Such a procedure would permit the avoidance of many errors and would facilitate the process of implementation of technical solutions in everyday practice.

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