

Advances in Production Management and Ergonomics

Volume1

**ERGONOMICS FOR PEOPLE
WITH DISABILITIES
DESIGN FOR ACCESSIBILITY**

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LODZ 2018

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PUBLISHER

*De Gruyter Open Ltd., Bogumila Zuga 32A, 01-811 Warsaw, Poland
Walter de Gruyter GmbH, Genthiner Strasse 13, 10785 Berlin, Germany
www.degruyteropen.com*



**Ministry of Science
and Higher Education**

Republic of Poland

XVIII Research-Technical International Conference: Ergonomics for People with Disabilities
"Social and Occupational Activation" – task financed under contract **608 P-DUN/2017**
from the resources of Ministry of Science and Higher Education allocated for activities
which disseminate the science.

**ISSN 2544-7610
ISBN 978-3-11-061782-5
ISBN (e-book) 978-3-11-061783-2**

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INTRODUCTION TO THE MONOGRAPH

Aleksandra Polak-Sopińska, Jan Królikowski, Magdalena Wróbel-Lachowska

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The world of developed economies looks at the problems of people with disabilities from a technical, social, psychological and informational perspective. Impacts in favour of people with disabilities are most often equated with the removal of barriers and integration. Nowadays, virtually every form of social and economic life should take in account inclusion and removal of barriers. Urban planning, the design of buildings, communication networks and the products, tools can be done from the perspective of removing barriers for people with disabilities. It is crucial to promote a way of thinking aimed at taking into account the needs of people with disabilities in the creation of all new civilizational solutions.

Monograph “Ergonomics for People with Disabilities: Design for Accessibility” presents interdisciplinary attitude to the issue of designing for people with disabilities. The aim of the monograph is to present the factors affecting life activation of people with disabilities (including “50+” and “mature” people) and the problems that people with disabilities face by the participation in social and professional life and the daily activities and how design for accessibility can help with solving those problems.

Concepts presented in the first part are focused on designing of products supporting inclusion such as wheelchairs, orthopaedic seats, carrier vests and hand tools. This part consist of five chapters.

Field of interest of second part of the monograph is how to design accessible socio-technical environment. The subject is presented in four chapters on two hospital case studies, backyard sensorimotor path case and integrated therapeutic environment case.

Third part is focused on universal design with ICT solutions. It consist of the concepts and analysis of solutions supporting people with disabilities and elderly people presented in six chapters.

Scope of the last part is human factor design for barriers reduction. In three chapters problems such deafness, dementia and professional activity of people with disabilities were presented.

Monograph includes the wide perspective of engineers, designers, architects, psychologists, sociologists, vocational counsellors and medicals that can inspire to new look at design for accessibility.

DESIGNING OF PRODUCTS SUPPORTING INCLUSION

COMPARISON OF TWO DIFFERENT CARRIER VESTS FOR SHOULDER-SUPPORTED CARRYING OF LOADS

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Abstract: Over a quarter of work-related accidents are related to load transport. The main problem arises from employee training in that it should not be centered on load transport safety techniques but on eliminating dangerous load transport. This is the most efficient way of reducing work-related injuries.

There are certain terrains in Colombia that make human labor the only means of transport. The variety in terrain is extensive, making complete mechanical system adaptability almost impossible.

The need to create a protective upper body system for load distribution, which guarantees manipulation free of Muscular-Skeletal Disorders (MSDs) at short and long terms for the user in difficult-access zones, contributed to the development of two systems “Carrier vest A” and “Carrier vest B”; comparing their kinetic behavior in a quantitative and qualitative experiment. The result of this investigation suggests that when biomechanics and ergonomic principles are taken into account for load manipulation (concept design requirements of the final Carrier vest B), the energy used can be reduced 26.66% if Carrier vest B is used in a situation where no protection is used, and 8.97% if Carrier vest B is used instead of Carrier vest A (initial concept). In the same way, the deformation percentage generated on the shoulder can be reduced in comparison with the use of Carrier vest A on a flat terrain in 32.97%, and 74.48% on the back. The difference in percent between deformation on the shoulder and back when using Carrier vest B (final concept) is of 93.57%, being higher in the back, which points out that the system stabilizes the vertebral column and transfers shoulder loads to stronger parts of the body as are the waist and hips; minimizing the Muscular-Skeletal impact of the upper body.

Keywords: Carrier-vest, shoulder-supported, manual-handling-loads, upper-protection, skeletal-muscle- injuries.

Introduction

Work-related accidents and their losses are one of the main problems of the industry, accounting for the world's economy by 4% of gross domestic product (GDP), according to the ILO (International Labour Organization). The annual loss

is approximately 1.25 billion (1'250 000 million dollars) for the global GDP [19]. In Colombia the cost of accidents is around 4.5% of GDP, representing \$ 7.76 billion per year; although it should be noted that the statistics of accidents and deaths deviate from reality, due to the underreporting of work-related accidents and diseases.

Although Colombia has improved compared to 1994, when it ruled El Sistema General de Riesgos Profesionales, it is still to position a genuine culture of risk prevention in workers; and taking into account the correlation between physiological, mechanical and/or ergonomic and psychosocial, causing Musculo-Skeletal Disorders (MSDs) in employees.

According to a survey conducted by the European Foundation of CT in 2010, about the working conditions of 15,800 workers in the European Union, it can be determined that 30% of the surveyed population defined constant back pain as the main cause of accidents, 28% think the cause is stress, 25% muscle aches and the remaining 17% from other causes. Due to Musculo-Skeletal Disorders, it is estimated that 120 million occupational accidents occur annually, 200,000 of them with fatal results, and from 68 to 157 million new cases of occupational diseases. According to a study performed, in Colombia, by The National Institute for Occupational Safety and Health (NIOSH) in 1998, 74.3% of occupational diseases reported were due to Musculo-Skeletal processes [7, 8].

World Health Organization (WHO) indicates that 60% of the population will suffer from back pain throughout their life, and the age of onset is usually between 25 to 30 years. In Spain, back pain is one of the most important causes of disability, accounting for 54% of work days lost. Some injuries that originate in the back are caused by the natural tendency to lift weights by flexing the trunk, because the back is not prepared to lift weights in highly inclined positions and resistance is within the back muscles and vertebrae ligaments.

According to ISO 11228, all loads over 3 kg can generate a significant lumbar back risk if performed under unfavorable conditions: frequent handling, if the characteristics of the load forces are averted from the body when turns or tilts with awkward postures are required, or if other factors such as humidity, temperature and noise are involved. Any job that implies a physical effort of lifting, lowering, transportation, pushing or pulling heavy objects, generates a risk for the worker in the manual handling of such loads [4].

Currently an increase is shown in the solution to protect the human body, with developments that support functionality with biomechanics, ergonomics and anthropometry, specifically in the defense industry and sport. The carrying of loads by troops is an important aspect of military operations, but generates a critical overload for ammunition and equipment, producing excessive fatigue that affects the ability to fight. Heavy loads directly or indirectly reduce performance and increase unnecessary deaths and lost battles. In recent years there have been some practical methods to reduce the stress load of soldiers in service, account the type of mission, environment, weather and terrain [11].

By implementing ergonomic solutions that improve productivity and increase comfort in intensive labor activities, such as a "load transfer device",

a portion of the weight and moment of the upper body tissues can be distributed from the lower back to the hips and/or legs [6].

Although there are body armor vests, avoiding injuries in the upper body of the user when there is activity in high-risk sports, or when handling loads that rub against the skin, and jackets that allow carry the load on the back or hips, there is not a device specifically designed to carry loads on the shoulders and/or trapezius. After analyzing 32 patents related to the distribution of body burdens and damping loads, it was found that 30 of them protect the shoulders [2, 9, 22, 23], 21 protect the trapezius [1, 10], and 23 protect the back [12, 20] in load bearing activities and extreme sports; concluding that it is necessary to protect these three sectors to ensure effective upper body defense.

The aim of this paper is to compare the kinetic behavior of two systems body protectors when handling loads in the upper body, showing how to take into account the biomechanical and ergonomic principles cargo handling, can reduce energy consumption and deformation, and increase postural stability.

Test objects

In the rural zones of Colombia, where vehicle access is inexistent, and the installation of public services is required, the workers in charge of installation are forced to walk with workloads and components necessary for the installation or maintenance. These activities present a high degree of difficulty, elevated manpower costs, prolonging of installation times and a high accident rate for workers. One of the heaviest components and most difficult to handle that must be transported are the cabling posts, which are usually made of wood and can reach 326 kg in weight and lengths of 12 meters. This type of transport must be realized individually or by groups, but actually does not count with any kind of harness of protective device that facilitates the job.

With reference to the modality of the load, the area of the body that is most needed corresponds to the shoulders and upper trunk. There are many existent ways to safely carry loads on the shoulders, as can be observed in [13]. The technique used depends on the characteristics of the load (size, shape, mass, etc.), the way of carrying the load, the experience of the person in handling loads and the protective equipment available for the job. This specific need contributed to the development of a protective body system to support loads in the upper trunk, which guarantees a risk-free manipulation for both muscles and the skeleton both short and long term, called Carrier vest A. It possesses an outer layer of thermoplastic material to protect the areas of the body involved, and foam to isolate the body from injuries produced by handling the load. In the shoulder area, there is a part of the same material mentioned that is embedded at the two extremities of the internal layer, in addition to a rubber that generates a curve forming a type of spring between the layering and the rubber. The fastening of the system is located on the lateral part of the body where the user

adjusts belts with different widths both anterior-posterior and shoulder width (Fig. 1a).

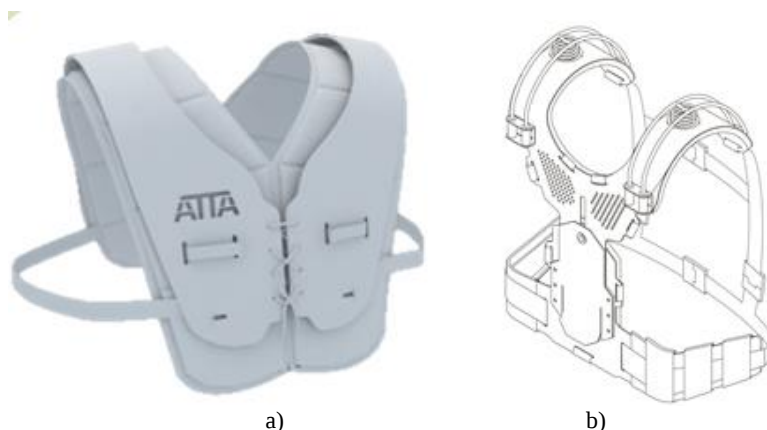


Fig. 1. a) Carrier vest A, b) Carrier vest B
Source: Project of Universidad EAFIT.

In order to design Carrier, vest A, a metric analysis was proposed with 150 men with specific characteristics, age identification (between 18 and 70 years of age), height, weight, anterior-posterior diameter, shoulder distance and anthropometric dimensions of the upper body and trunk. The most important aspect at the moment of defining the result, was finding men with heavy workloads, where great amounts of physical activity are involved throughout long hours of work. Keeping in mind the design criteria related to the biomechanics, ergonomics and anthropometrics, and its applicability in the actual market, another design proposal was created, Carrier vest B, in order to better distribute loads on the body, as can be observed in Image 1b. This system consists of a metallic structure that communicates the upper body with the back and lumbar spine, allowing loads located on the shoulders to be distributed to stronger parts of the body, as are the hips and waist. Such design stabilizes the spine in the recommended way and avoids any deviation from this posture when the user bends over or rises. In the same way, it presents a system of elastic elements in the shoulder zones, to cushion the punctual weight generated by the load and distribute the reactions to different parts of the body.

Experimental setup

Both Carrier vests were tested to identify quantitative experimental axial load strains at specific points, and qualitative tests to determine the perception, metabolic consumption and heart rate changes in the stages of pre-stress, stress and post-stress charge of certain activities.

Quantitative Test

All trials were conducted on a load carriage simulator designed and built by the Design Engineering Research Group at the Universidad EAFIT, Medellin, Colombia. This simulator was used to compare shoulder strains under three different load distributions for both Carrier vests. In order to control as many variables as possible, the simulator device was constructed simulating the upper part of a human body with the same dimensions used to design and manufacture the vests (Fig. 2), and was instrumented with two 45°-rectangular strain gage rosette in order to measure strains in all directions, one in the upper part of the shoulder and another in the lower part of the posterior shoulder. The structure was manufactured in regular steel.

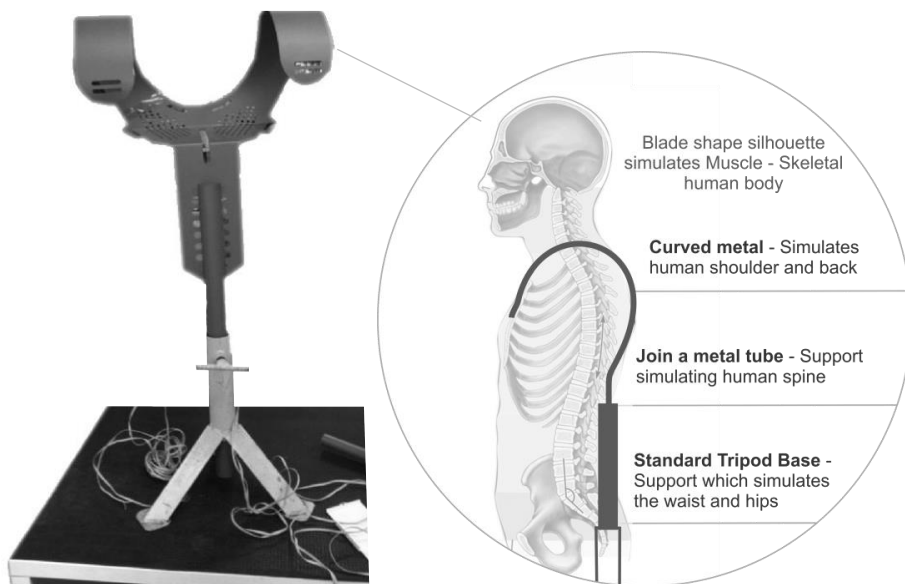


Fig. 2. Metal structure

Source: Project of Universidad EAFIT.

The strain was used as an indirect way to measure the stress on the shoulder considering it as an isotropic material [15]. So, the strain and the stress are proportional measures affected by a physical property of the material. In this way, the strain is a straightforward measure of the stress on the shoulder while load carrying. Although the human body doesn't act as a material with elastic and plastic deformation, with different rates in the test the maximum deformation of the metal structure was identified in the areas that simulated the human shoulder and back, a certain time. Behavior was evaluated in Carrier vest A and Carrier vest B with a 45-pound weight, in accordance with ergonomic load limits in three different situations, tilt limit is usually in rural areas horizontal shift (0 degrees), upward displacement (9.5 degrees) and downward displacement (170 degrees).

Qualitative Test

Participants and protocol

For Product validation, perceptual tests were conducted with 8 participants who have similar physical characteristics, which covered a distance of 20 meters on level ground with a 50-pound load on their shoulders under three different conditions: Test 1: Unprotected/Test 2: Use Carrier vest A/Test 3: Use Carrier vest B. Participants who performed the tests are young men (average age 25 years, mean weight of 73 kg-f and average height of 1.78 meters) that are not used to handling loads in remote areas but could physically perform the task of transporting the burden on their shoulders in rural areas. It should be noted that the level of resistance of the operators of the electricity sector is higher, as they are performing activities in their daily lives; know how to overcome the problems at the right time, and have tactics and ways to cope with the burden to get paid a little more on the way, but these are issues that do not affect the initial qualitative assessment Carrier vest.

Measured Parameters

The qualitative results obtained were in accordance with the difficulty of the task and with the magnitude of the physical loads. In the first variable, the most important information of the 8 participants was grouped: age, weight and height. In the same way, the time taken to complete the task, the speed, posture and facial expression were identified and measured by perceptual scales. For the magnitude of the physical loads, the direct physiological aspects related to oxygen consumption (ISO 8996:1990), were determined by calculating the basal metabolism that represents the necessary metabolic consumption in order to keep the vegetal functions (breathing, circulation, etc.) working, the postural component, the type of work and displacement, the global metabolic consumption, the mean metabolic consumption during a specific time and the speed of translation in relation to the load [5].

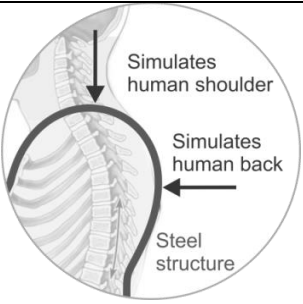
The indirect physiological aspects were perceived by analyzing cardiac frequency (cardiac frequency recuperation ability in relation to effort); investigating the surgical, allergy, cardiovascular, respiratory, and metabolic history of the participants, and the criteria present in relation to the stress test, in knowledge of the pre-stress, stress and post-stress variables. The psychophysical variables that were analyzed are related to Borg's perceived stress scale, that presents scales from 0 to 10, 0 being a perception of rest and 10 being one of highest stress [3, 16].

Results

Quantitative

To simulate load at level ground, with Carrier vest A the maximum deformation of the shoulder was measured at 17.44 $\mu\text{m/m}$ and 712.67 $\mu\text{m/m}$ on the back, while the Carrier vest B maximum values of 11.69 $\mu\text{m/m}$ at the shoulder and 181.85 $\mu\text{m/m}$ on the back were obtained, indicating reductions of 32.97% strain on the shoulder and back 74.48% relative to the first test. By tilting the plane to 9.5 degrees to simulate an uphill walk, the maximum strain generated on the shoulder with Carrier vest A was 90.96 $\mu\text{m/m}$, an increase of 80.82% compared to the results obtained on flat land, while the tilt level to 170.5 degrees simulating a walk downhill, shoulder strain decreased to 56.68 $\mu\text{m/m}$ increasing 69.23% over flat terrain. By tilting the plane uphill, the maximum strain generated on the back when using the final prototype Carrier vest B was 574.83 $\mu\text{m/m}$, an increase of 68.36% compared to the flat field test, while tilting the downhill plane, strain decreased back to 221.83 $\mu\text{m/m}$, up 18.02% with respect to the ground plane and decreasing by 58.64% compared to results generated using the Carrier vest A (Table 1).

Table 1. Maximum strains reached in the quantitative test

Type of protection used	Maximum deformations [$\mu\text{m/m}$]				
	Location of rosettes		Horizontal ground	Ground up	Ground down
Carrier vest A		Simulates human shoulder	17.44	90.96	56.68
Carrier vest B		Simulates human shoulder	11.69	-----	23.44
Carrier vest A		Simulates human back	712.67	-----	-----
Carrier vest B		Simulates human back	181.85	574.83	221.83

Source: Project of Universidad EAFIT.

Qualitative

By identifying the characteristics, behavior and perception of the efforts of each participant in performing the three tests, a series of observations and conclusions were collected that identified the advantages and disadvantages of the final design, proposing improvements and recommendations for the

implementation of the artifact in a real market. The average maximum speed reached by the eight participants was 4.82 km/h in a test that used the Carrier vest B increasing by 15.97% compared to Test 2. With respect to the limit values, the maximum speed reached in the test that used the Carrier vest B was 7.2 km/h and the minimum speed reached was 2.66 km/h in the unprotected test. To identify the arduous nature of the task it was necessary to observe posture, facial expression, according to the rating scale, the words spoken by each participant and the signs of labored breathing.

Labored breathing signals are perceived at the end of each test, on a scale of attributes “low”, “medium” and “high”. The low forced respiration signal decreases when passing each test, in Test 1 62.5% of the participants had a low signal, whereas in Test 3 this percentage decreased to 12.5%. The half-forced respiration signal increases to pass the tests in Test 1, 37.5% of participants had a mean signal, whereas in Test 3 this percentage rose to 87.5%. In order to identify the magnitude of the physical load during the tests, it was necessary to identify the physiological characteristics related to direct aspects (oxygen consumption) and indirect (recuperation ability of cardiac frequency in relation to fatigue); and the psychophysical characteristics (Borg’s perceived strain scale) of each participant. The oxygen consumption due to metabolic activity was found for each participant during a certain time. When working conditions vary during working hours, is necessary to balance the energy consumption values over time. For this it was determined that the activities be done by the participants in each test, and in a defined time for each. To determine the metabolic consumption of each activity, it was necessary to refer to the tables provided by the National Institute of health and safety at work [17] and used in the equation (1) for each test.

$$M = \frac{\sum_{i=1}^N M_i \times t_i}{T} \quad \text{being } T = \sum_{i=1}^n t_i \quad (1)$$

The highest average energy expenditure occurred in the Test 1 (unprotected) with a value of 215.46 Watts/m², while the lowest was in Test 3 when using the final concept Carrier vest B with a value of 158 watts/m², in Test 2 (Use Carrier vest A) the result was 173.58 watts/m². With respect to the limit values and the change in consumption of each participant, in Test 1, the variation in energy expenditure was between the 195 and 223 watts/m², while in Test 2, the change in consumption was more unstable among participants, the highest score was 204.1 watts/m, and the lowest of 122.9 watts/m². Like the previous test, in Test 3 also introduced instability between the results of each participant, the highest consumption obtained in this test was 174.7 watts/m² the lowest of 136.7 watts/m². To determine the ability of recovery from fatigue in relation to heart rate, it was necessary to know the medical history of the participants, of which 50% have had surgery, 63% have no allergic setbacks, 100%

no cardiovascular and/ or respiratory diseases, and 75% have no history of metabolic diseases. When analyzing resilience of fatigue in relation to heart rate of each participant, it was determined that 50% of participants had a mean daily activity fatigue, 38% lower and the remaining 12% high, 87% had a pre-test power, the mood of the 50% of the participants was high and 25% medium. 63% of participants had good initial conditions, while for 25% the conditions were bad, and 27% have impaired concentration and/or memory. In Test 1, 75% of the participants had higher stress peak at the beginning of the test in load-holding time, the remaining 25% showed a greater effort by the end of the test. In Test 2, 100% of participants had more effort at the beginning and in Test 3 to 75% at the end. The results of the criteria considered in the post-effort indicate that 37% of participants experienced fatigue after 24 hours of tests performed, 25% reduced their daily activities by fatigue and 100% did not feel disturbed his sleep.

An analysis of the level of pre-stress, stress and post-stress of each test, comparing the change in heart rate in beats x minutes of each participant. The level of pre-and post-effort remains constant in all tests, being an independent variable of these. The average heart rate of the pre-stress of the participants was 78.5 beats x minutes, the maximum value obtained was 108 beats x minutes and the minimum value was 64 beats x minutes. While the average heart rate of post-effort of the participants was 78.25 8 beats x minutes, the maximum value obtained was 90 beats x minutes and the minimum value was 60 beats x minutes. The recovery percentage of participants between the pre-and post-exertion effort was 99.68%. By linking these data with the effort generated in Test 1, it can be concluded that the average heart rate of the participants was 99 125 8 beats x min, increasing by 20.80% compared to the frequency of pre-stress, and 21.06% in the post-effort. In Test 2 the average heart rate of 8 participants was 105 beats x minutes, an increase of 25.23% compared to the frequency of pre-stress, and 25.47% in the post-stress. In Test 3 the average heart rate of participants was 112 875 8 beats x min, increasing by 30.45% compared to the frequency of pre-stress, and 30.67% in the post-effort. With regard to the Heart rate limits, even for Test 3 showed the highest average value (112,875 beats x min), Test 1 showed the peak frequency in one participant (138 beats x min), while in Test 2 was exposed minimum peak rate (69 beats x min). The test that showed less increase of heart rate in comparison with the frequency in the pre-effort and post-effort was unprotected (20.80%) (21.06%) and higher magnification which was when using Carrier vest B (initial concept) (30.45%) (30.67%).

Discussion

Quantitative analysis

Despite Comparing the deformations in the metal structure on the points where the rosettes were placed on the shoulder and back, on a flat surface and

tilted (down) a decrease of over 50% can be identified when use Carrier vest B instead of Carrier vest A. The percentage of decrease in strain on the shoulder when using the Carrier vest B on a flat and sloping ground (down) was 10.91%, being higher by restricting degrees. By placing the framework on a flat terrain, the percentage of decrease between the use of Carrier vest A and Carrier vest B increased by 4.93%. By increasing the angle of inclination of the ground (down) the percentage of deformation increased with respect to the ground plane in a 68.36%, while changing the angle (up) is decreased by 61.40%.

The results show that the angle of inclination of the land where most deformation is generated in the back when the final concept is used, is up to 9.5 degrees, with a maximum value of 574.83 $\mu\text{m}/\text{m}$; leading to analyse the design Carrier vest B, which allows to distribute efforts appropriately located in the upper parts of the body to stronger parts such as the back, hips and waist. When climbing an incline, the load has to move and position the shoulder blade and back, so the operator must overcome that motion with his hands, directing the charge status. While using the initial concept, the maximum deformation occurring at the back was 712.67 $\mu\text{m}/\text{m}$ on the ground plane, this is because the thermoplastic material used (polystyrene) doesn't adequately absorb loads and the design of the same does not restrict the curved longitudinal movement produced by the loads, generating greater deformation in the rear of the structure. When carrying weight on the shoulder twisting decreases, but not the compression of the spine. The situation of an inclined plane rising (9.5 degrees) marked the highest strain on the back when using Carrier vest B (final concept) with a value of 574.83 $\mu\text{m}/\text{m}$. It is assumed that this finding would increase if the loads are distributed between two by a crossbeam, and that the individual capacity is reduced due to the difficulty of synchronizing the movements or obstruct vision. In general, in a two-people team, the lift capacity is 2/3 of the sum of the individual capacities.

Qualitative analysis

In an analysis of the arduous nature of the tasks in each test, one can assume that posture, facial expression and verbal manifestations improved when using Carrier vest B (final concept). With the results, it is understandable that the pain threshold increases when the load increases while manipulating a load with several people; it is necessary to acquire teamwork and good communication between the operators. Energy expenditure produced by physical activity, is used to perform a series of activities or behaviors involving body movement (Muscle–Skeletal activity) [21]. If using the Carrier vest B decreases energy expenditure of activity test, it can be assumed that the prototype improves operator working conditions and increases work capacity, decreased the effort because the body has increased resistance when performing physical activity.

Although the average heart rate of the 8 participants in Test 3 was the highest relative to the other, with a value of 112 875 beats x min, the average

round metabolic consumption was lowest, with a value of 158.25 W/m². It is known that there is a linear relationship between the metabolic consumption and heart rate, by means of the following equation [14].

$$M = (4X FC) - 255 \quad (2)$$

where: M is the metabolic rate in W/m² HR is heart rate in beats per minute.

If the heart rate obtained in Test 3, is replaced in equation (2), the result is serious metabolic consumption 226.5 W/m², 30.13% higher than the result obtained during testing. If we replace the metabolic consumption value in equation (2), heart rate would result 95.81 beats per minute, decreasing one 15.11% in relation to the pulses obtained during testing, proving to be the smallest value among the three tests, a decrease of 3.34% compared to unprotected test where a frequency of 99.125 was obtained beats per minute, probably indicating that participants had a higher heart rate at pre-stress to the test start, because the reduced effort of the task, the energy consumption decreases by increasing work capacity and user load.

Conclusions

The result of this research suggests that when considering the biomechanics and ergonomic principles for cargo handling (design requirements of the final concept Carrier vest B), the energy cost can be reduced by 26.66% when using the Carrier vest B in a situation where no protection is used, and a 8.97% when using the °Carrier vest B instead of Carrier vest A (initial concept). Also, the percentage of deformation generated in the shoulder can be reduced compared with the use of Carrier vest A on a ground plane in a 32.97% and 74.48% at the back. The percentage difference between the shoulder and back strain when using Carrier Vest B (final concept) is 93.57%, being higher in the back, which suggests that the system, in order to stabilize the spine loads, transferred loads from the shoulder to stronger parts in the human body such as the waist and hips, minimizing the Muscular- Skeletal impact in the upper body.

Carrier vest B the design adjusts and adapts to the lumbar and stabilizes the posture of the user, allowing the efforts transmitted by intervertebral disks. When handling a load with improper posture, the core does not stay in the center of the intervertebral disc, but moves by the impingement of the vertebral platforms. Repeated efforts abnormal movements (large amplitude deflections, rotations, etc.), causing a progressive deterioration of the intervertebral disc.

To determine the resilience was necessary to know the personal history of each participant and the initial conditions of the pre-test effort. The results demonstrate that group handling of loads requires prior knowledge of how to deal with the weight of the face, the terrain and the type of selected grid. In this

case the participants are young men who are not used to handling loads and communicate as a team for a specific purpose that addresses leadership.

The final design solution distributes the loads of the shoulders and/or trapezius and lumbar spine to the hips and waist, enhancing strength and operator comfort when handling heavy loads. By placing the column in a proper position, and prevent the tilting of the column twist during transport, you can walk aligning the movement over the midline of the body, as the diversion of this position produces an imbalance of forces generating a torque (roll when walking) the body subconsciously attempts to reduce the imbalance of forces. When a person is standing, the spine transmits to the lower weight of the head, trunk and upper limbs or any other charges. The lumbar vertebrae, which are located in the lower part of the spine, support the total load. This should lead and frontally close to the body, symmetrically dividing the two-arm weight [18].

Acknowledgements

The authors would like to thank to COLCIENCIAS by accepting this project in the call “Joven Investigador”¹ and providing resources with the University EAFIT for good development and project completion.

References

- [1] **A'Costa, A.:** Gun Recoil Protector. US 1985.
- [2] **Ball, R.:** Pivoted adjustable shoulders pad. US 1992.
- [3] **Burkhalter, N.:** Instrument evaluation of Borg's perceived exertion scale in cardiac rehabilitation. *Revista Latino-Americana de Enfermagem* 4 1996.
- [4] Council of Occupational Safety & Health: Guidance notes on Manual Handling Operations. Retrieved 16-04-2012, from <http://www.labour.gov.hk/eng/public/oh/GN-MHO.pdf>.
- [5] **Cuixart, S.N.:** NTP 323: Determinación del metabolismo energético 2000.
- [6] **Fathellah, F.A.:** Musculoskeletal disorders in labor-intensive agriculture. *Applied Ergonomics* 2010.
- [7] **Fishman, E.:** The impacts of public bicycle share schemes on transport choice 2011.
- [8] **Gil-Monte, P.R.:** Riesgos psicosociales en el trabajo y salud ocupacional. *Revista peruana de Medicina Experimental y Salud pública*, 29(2), 2012, 237-241.
- [9] **GoldSmith, H.:** Athletic shoulder protector 1947.
- [10] **Gregory, J.R.:** Upper body protector US 1985.
- [11] **Knapik, J.J., Harman, E., Reynolds, K.:** Load carriage using packs: a review of physi-ological, biomechanical and medical aspects 1996.
- [12] **Lamson, K.L.:** Spray coated foam protective athletic 2009.
- [13] **Legg, S.J.:** Comparison of different modes of load carriage. *Ergonomics*. 28:197221, 1985.
- [14] **Maestre, D.G.:** Ergonomía y psicosociología Fc. Editorial 2009.

¹ Young researcher.

- [15] **Medina, P.J.O.:** Esfuerzo y deformación 2010.
- [16] **Morgan, W.:** Psychological factors influencing perceived exertion. *Journal of Medicine and Science in sports* 5: 98 1973.
- [17] **Nogareda Cuixart, S.:** NTP 323: Determinación del metabolismo energético, Centro Nacional de Condiciones de Trabajo, 2000.
- [18] **Punnett, L., Wegman, D.H.:** Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *Journal of electromyography and kinesiology*, 14(1), 2004, 13-23.
- [19] **Ramírez García, H., Torres Nieto, A.:** Diseño de un proceso metódico de la accidentalidad en occidente de Colombia. Retrieved 20 de Febrero de 2012, 2004.
- [20] **Van, C.S.:** Body Armor. US 2011.
- [21] **Weinsier, R.L., Schutz, Y., Bracco, D.:** Reexamination of the relationship of resting metabolic rate to fat-free mass and to the metabolically active components of fat-free mass in humans 1992.
- [22] **Wilfred, E.L.:** Shoulder Protector. US. 2000.
- [23] **Williams, P. D, Mich, D.:** Shoulder protection device. US 1982.

ANALYSIS OF USE AND THE SEARCH FOR DESIGN FORM AND CONSTRUCTION OF ORTHOPAEDIC SEATS AND WHEELCHAIRS INTENDED FOR CHILDREN AND TEENAGERS

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Abstract: The article presents experiences of the authors from the research and development project titled: “Study of orthopaedic seats, particularly for children and teenagers with paralysis and paresis (triplegia, tetraplegia, diplegia, hemiplegia or crossed hemiplegia)”. The study presents the design approach of the team of designers from the Strzemiński Academy of Arts in Lodz and selected solutions which will be implemented by LIW Care Technology – a company that produces wheelchairs for children with cerebral palsy.

Keywords: orthopaedic wheelchairs, innovative constructions of orthopaedic wheelchairs for children and teenagers, rehabilitation aids, system orthopaedic seats with the possibility to switch, wheelchairs for children with cerebral palsy.

Design research and development works

More and more companies which produce equipment for the disabled people pay attention to the design when competing for customers on the market. Finally, the aesthetics and an easy process of use of the proposed solutions are as important as reliability and dependability of materials. Thanks to government programs and the help of EU, which supports companies, it is possible to form cooperation between scientists – designers and producers who need advice in terms of form and ergonomics of the implemented products. Within the scope of the research and development project realised as part of the agreement between the Strzemiński Academy of Art in Lodz and LIW Care Technology three types of seats and four types of frames produced for children and teenagers with movement disabilities were analysed in terms of ergonomics and use. The hereby article aims at presenting each stage of works and indicate the legitimacy of such analyses and design concepts in interdisciplinary environments combining industrial designers, graphic designers and constructors.

The knowledge, experience and very well-mastered production engineering are invaluable in such cooperation.

Why is it worth using the knowledge and experience of outside interdisciplinary teams when implementing new products onto the market?

Almost any production facility has its own office of constructors, technologists or designers responsible for the design and look of the products it makes. Very often however, such a team lacks a designer educated at the Faculty of Industrial Design of the Academy of Art. Graduates of design degree courses at Academies of Art can be a perfect contribution for teams responsible for implementation and production. More and more often, companies notice the need to seek advice of an artist designer.

The described form of cooperation relates to an industrial design analysis in terms of ergonomics and use of orthopaedic seats and wheelchairs dedicated to children and teenagers with movement disabilities conducted by an interdisciplinary team, and creating a proposal of a new design form for the analysed products.

Works were realised as part of the topic titled: Conducting research and development works by LIW Care Technology in order to create a system of orthopaedic seats particularly for children and teenagers with paralysis and paresis (triplegia, tetraplegia, diplegia, hemiplegia or crossed hemiplegia)". The project was partially financed with EU resources within the scope of action RPO WŁ I.2.2 Regional Operational Programme for Lodz Region for the years of 2014-2020, Priority Axis I. Research, development and commercialization of knowledge. Action I.2 Investments of companies in research and innovations Subaction I.2.2 Projects B+R of companies [2].

The research team from the Strzemiński Academy of Art (ASP) included three designers of Industry Design, a graphic arts designer, and a constructor with years of experience in cooperation with the designer of Industrial Design.

Analysis of current state – basic problems to be solved and users' expectations

The analysis included products of LIW Care Technology. Their construction and design form were created by the design team of the company. Apart from typical analysis of formal and visual solutions performed on the basis of the supplied materials, the ASP design team decided to recognise the problem in a complex way.

In order to do that, groups of two people conducted research in the form of participation observation including interviews with the users. Courtesy of the school and the Foundation for children "Kolorowy Świat" which cooperates

with the company, it was possible to observe everyday activities performed by the parents, caretakers and therapists while transporting the children to school, to their classes and during therapy. It should be emphasised that the analysis covered wheelchairs for special users i.e. children with severe cerebral palsy. The special character of the situation is that the children are fastened to the seats with the use of straps and stabilisers, which help maintain correct body position, practically all day. Their disabilities are often connected with the tendency to tauten on the seats or straighten their bodies constantly fighting with the stabilising elements and the wheelchair's construction.

The basic problems observed during the research proved the following inconveniences:

- the backs of some seats can break even after one year due to the specific way in which they are used – it is a big problem for families which are not well-off, as the subsidy for such wheelchair is granted every five years,
- the construction of the spine type requires regulation too often with the intense use that takes place at school,
- after a couple of months the wheels in which standard wheelchairs are equipped start to block, which impairs the dynamics of turning and the comfort of pushing,
- the size of the wheels and the material they were made of does not make it easier to cross the thresholds between classrooms,
- the 3d upholstery fabric used stimulates sweating in children and very quickly wears down, especially under elbows and buttocks,
- the wheelchairs are too heavy,
- the strapping system is not perfect – the buckles wear down fast.

Conversations with the children's carers, the parents and the therapists allowed us to define their expectations in the field of wheelchairs for children:

- the most often repeated demand was for the wheelchair to be “pretty”, everybody emphasised that aesthetics of the proposed solution has huge importance, especially for families, which do not want the wheelchair in which their child spends almost all day to additionally remind them about the disability,
- due to fast changes in the children's height and weight observed in users under 16 years old, it is necessary to take into account many regulations, which will allow precise adjustment of the wheelchair to the children; the wheelchair is expected to “grow” with the child,
- due to the need to quickly stop the wheelchair in a stable position sometimes it would be useful if there was a function to block all wheels in the same time,
- users noticed the lack of a bag for keeping and carrying useful items,
- regulation of the height of arms and pelvis stabilisation are incredibly important,

- while playing in a group, it would be very comfortable to be able to lower the seat so that the child could make eye contact with other children s/he is playing with, who are very often on the floor,
- due to health reasons, it is essential for the wheelchair to provide comfortable support for all body parts (there cannot be any unsupported places); what is more, the seats for children with cerebral palsy must offer maintaining straight angles between given parts of the body such as foot – calf, calf – thigh, forearm – arm,
- an extremely important element of a wheelchair's equipment is the footboard which should provide the possibility to change the angle; there must be support under the whole foot; it is better to assemble two separate footboards than one, which allows separate adjustment and easier access to the child from the front; it is also important for the footboard to offer the option to strap the feet to it in a simple, fast and stable way,
- because of the need to stabilise the children in the wheelchairs a durable system of fast and regulated strapping in must be provided,
- it was also pointed out that it would be very useful to have handles for pushing all wheelchairs, not only the stroller-type,
- another important element of equipment is a tray which can be attached in front of the child, where s/he can eat, play or practise; such a tray should be relatively big and should have a border to stop things from falling down.

Analysis of the current state – the producer's possibilities, accessible technologies, price competitiveness in the sector, and the producer's expectations

Another stage of the analysis was a visit in the production facility and an attempt to get familiar with the production engineering and the possibilities to make changes which are as non-invasive as possible for the process. It turned out however, that many of the criticised elements are ready-made, in compliance with the European and Polish norms. The company has very modern machines including a waterjet cutting machine, a press brake, a spindle bender and a hydraulic bender for pipes and profiles, a milling machine and a CNC lathe [2]. Most of the machines were bought within the scope of the described project or previous EU projects. Thus, the main purpose of the company is to make use of the technologies as much as possible during the procedure of implementing the system solution for constructing seats and wheelchairs.

The commissioning party is a company which is well-established on the Polish market and is now entering the European and world markets dynamically, but the price is their best asset. That is why many of their solutions use ready-made elements and the finishing materials – such as fabric – are also those

commonly used in similar solutions. Customers are accustomed to the construction solutions introduced by LCT and the design they offer seeing the situation as a combination of a well-known quality with an attractive price. A sudden change in the materials that are used would definitely improve the quality, but it would also influence their price by increasing it. Such solution is currently hard to accept as it would force them to compete in a field which is new for them with companies with much bigger budget and experience. Thus, the task for the ASP design team became even more challenging. What is more, the documentation they received had some solutions that had been tested and received positive opinions by the company's constructors and technologists.

Design solutions – the company

The company itself had its expectations, initial assumptions and first construction solutions for the whole system. The design concepts which were created are the result of the producer's experience from years of producing this type of devices. On the basis of development of their own constructions and observing the competition in the field. Sales representatives delegated to various parts of Poland and other European countries are a very valuable source of data concerning expectations relating to the offered products, as depending on the geographic region customers have different expectations or habits and different norms and guidelines apply in terms of details.

The team of designers and constructors started working on implementing the system solution for the noticed problems on the basis of their past experience and new technology possibilities. The aim of the project was to create and develop a system of orthopaedic seats with seven elements with the possibility to switch frames and seats. As a result of the realisation of the project, a product innovation was implemented, which includes new functionalities, not accessible before, dedicated to children and teenagers with disabilities. The project is an answer to current challenges and directions of development on the market of medical products for the disabled and to the needs signalled by the end receivers. The effect of the project is a new product in the form of orthopaedic seats. The system consists of seven elements and each one will be used in the scope defined for it, thanks to its unique features.

Orthopaedic seat for children – technical elements of the product: seat, back support, hip stabilisers, chest stabilisers, abduction mechanism, single or double footboard, hip belts, vest, tray, upholstery. The product will be intended for children – the length of the back not less than 50 cm. The possibility to be mounted on different frames: rigid type indoor frame, high-low indoor frame and outdoor frame. The product will be dedicated to the group of patients with cerebral palsy, muscle dystrophies, various types of paralysis, spinal cleft, spina bifida, or disabilities caused by spine injuries.

Orthopaedic seat for teenagers – technical elements of the product are the same as in the seat for children. The product will be intended for teenagers – the length of the back not less than 60 cm. The seat will have the option to be mounted on different frames: rigid type indoor frame and outdoor frame. Due to its size, it will not be possible to put it onto the high-low type frame or to the light stroller-type frame. The product is addressed to the group of patients with cerebral palsy, muscle dystrophies, various types of paralysis, spinal cleft, spina bifida, or disabilities caused by spine injuries. An innovative function which distinguishes the product will be a system for pelvis correction which will make it possible to raise the left or right ischiatic tuber in order to position the pelvis.

Seat for the special needs stroller – a special stroller-type wheelchair will be intended for transporting children (the length of the back not less than 55 cm). The seat will have the option to be mounted on various frames: rigid type indoor frame, high-low indoor frame, outdoor frame, and light stroller frame. The wheelchair will facilitate everyday care over people who require transport and their disabilities make it impossible to move on their own, sit or stand correctly. The product is dedicated to children with paralysis and paresis (triplegia, tetraplegia, diplegia, hemiplegia or crossed hemiplegia).

Rigid type indoor frame – the product is dedicated to be used with orthopaedic seats. It is equipped in wheels and a mechanism which regulates vertical height. It will be intended for all types of seats: orthopaedic seats for children, teenagers and the seats of the special needs stroller. The frame will be designed in two sizes: up to 60 kg (for orthopaedic seats for children and for the special needs stroller) and up to 100 kg (for the orthopaedic seat for teenagers).

High-low type indoor frame – the product will be dedicated to be used with orthopaedic seats. It is equipped with a mechanism which allows placing the child low above the floor. The lowering mechanism will move the seat along an arch offering the possibility to place the child lower than with the use of a rigid type frame. This function is especially important in situations, where the disabled child is playing with non-disabled children. The regulation of the height of the seat makes it easier to maintain eye contact and enables using the device with tables of different heights. The product is intended for the following seats: orthopaedic for children and the special needs stroller. The frame is designed in one size – up to 60 kg.

Outdoor frame – the product is dedicated to be used with all types of orthopaedic seats. It is equipped with a brake, a handle for pushing it and big wheels adjusted for difficult terrain: stones, forest. Without the mechanism to regulate the height of the seat platform.

Light stroller frame – the basic frame for the seat of the special needs stroller. Technical features of the product: foldable to transport size, the option to mount the seat in different directions (facing forward or rearward), tilting the seat backwards, stopping brake, regulated handle for pushing, wheels.

Design solutions – industrial designers

After conducting profound analyses of the use process, production process, technologies which can be used in order to improve the products, and after getting familiar with the concepts presented by the company, the design team started working on selected aspects of the seats and wheelchairs. Quickly, it turned out that it would not be possible to redesign everything and create a very consistent line in terms of style for all the elements. Thus, it was decided that design works will mainly aim at simplifying the use process and the production of selected elements. The biggest challenge was the fact, that many things could be changed but the limited final price of the product would not allow a lot of modifications. We searched for solutions which include using EVA foam or sewing cases made of terrycloth [1].

During consultations with the company, it turned out that EVA foam, even though fulfilling all the norms, seems too hard for the parents and that is why they would choose a seat with slightly softer material. The proposed innovative combination of EVA foam with a case made of terrycloth was supposed to provide good ventilation, air circulation and good water channelling. The design team even found properly prepared terrycloth fabric coated with anti-bacterial nano molecules, which additionally increased the hygienic values of the product. Finally however, the possibility to use those materials was postponed due to their higher price [1].

First ideas for the style appeared together with names coming from birds and colours connected with colouration.

Necessarily not all of the suggested changes – even though extremely interesting for the company itself – could be implemented. As the EU subsidy made it possible to buy new machines for bending pipes and metal processing it was decided that the works would focus on the construction of wheelchairs and the back of seats in a way that allows the production process to take place in the company's facility. The shapes of seats formed by an injection molding machine required ordering a new form, so here as well it was possible to introduce modifications in a way that allowed creating objects which were in compliance with the description and the customer's expectations [1].

Sample solutions for the mechanical construction were created from metal components, aluminium profiles, steel profiles, mass-produced elements delivered by subsuppliers and selected elements made with the use of lost-wax casting technology and plastic injection moulding technology. The designs were directed towards improving or adding functions of selected products taking into consideration producing small series or individual production of medical items. A crucial assumption was the necessity for the mechanical elements of given products to be able to be made with the resources of the mechanical department at LIW Care Technology [1].

Orthopaedic seat for children – consisting of a seat, back support, hip stabilisers, chest stabilisers; a very important thing was the abduction mechanism for the legs, a single or double footboard was planned, the length of

the back not less than 50 cm. The design offers the possibility to mount the seat on different frames: rigid type indoor frame, high-low type indoor frame and outdoor frame. There were three versions of the seat which fulfil all the expectations. The basis for the construction and material assumptions for the product was introducing elements made of EVA foam; nevertheless, due to the cost of the material itself and its processing the company did not decide to develop the concept [1].

Orthopaedic seat for teenagers – technical elements of the product are the same as in the seat for children. The product will be intended for teenagers – the length of the back not less than 60 cm. The seat can be mounted on a rigid type indoor frame and an outdoor frame. What is especially important, is the function which distinguishes the product among the offer of competition i.e. the system for pelvis correction, which will make it possible to raise the left or right ischiatic tuber in order to position the pelvis. Both the therapists and the parents emphasised the usefulness of the solution [1].

In this design concept there were elements which could be made of EVA foam or some other plastic using the method of injection moulding as well; however, the most important aspect of the concept is dividing the back into panels where the number of panels depends on the expected height of the back and can be adjusted to individual expectations of the user. This way it would be possible for the product to “grow” with the child [1].

What is innovative in the project is the spindle for regulating the stabilisation of thighs, hips and under arms stabilisers from the outside. This innovative, patented solution enables smooth and slow screw regulation of the position of the stabilisers with an additional function of quick opening (letting-up) in order to take out or put a child in the seat easily. It is very important from the point of view of the users, carers or parents that full stabilisation of the child can be achieved quickly and without using any tools such as spanners or a screwdriver (Fig. 1) [1].

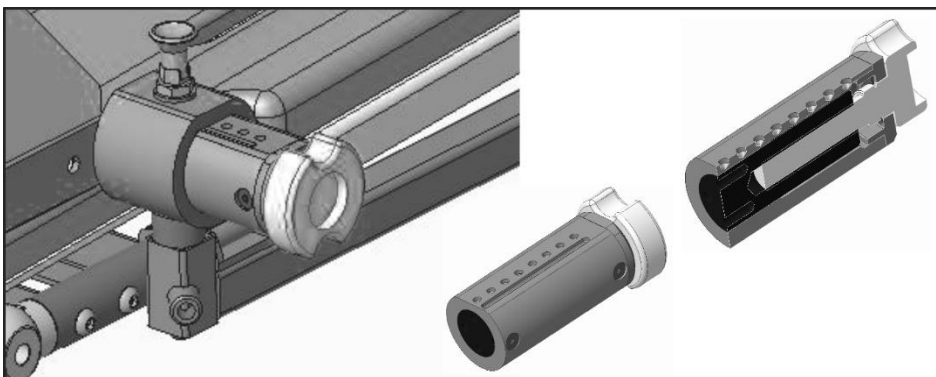


Fig. 1. Spindle for stabilising with smooth regulation
Source: [1].

Another very interesting proposal in the product was the armrest which was designed in a way that provides easy, smooth and fast regulation of the height, forward-backward positioning and the angle of support of the arm. The bearer of the armrest made with the use of lost-wax casting was also designed in a way that allows regulation without the use of any additional tools [1].

You should notice the details of the armrest – it ends with an ergonomic moulding. Its shape protects the arm against involuntary slipping, which happens often in children with cerebral palsy. This type of seat also has another advantage, which is the possibility to change the angle of the seat simultaneously with the armrests. Their base is made of an aluminium casting which offers the option to regulate height, angle and depth of the armrest, with an additional support for the elbow at the back, above the forearm (Fig. 2).

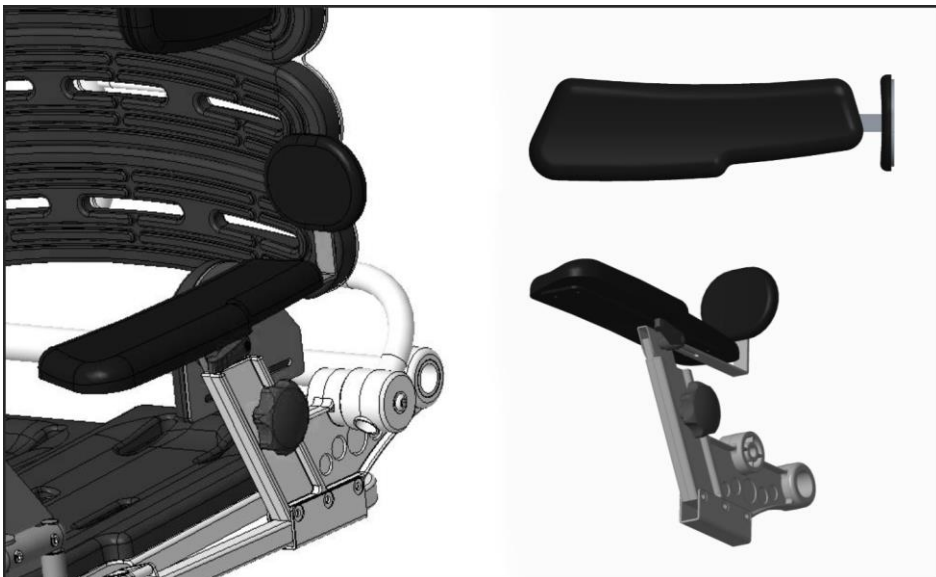


Fig. 2. Armrest with regulation of height and angle, which prevents slipping of the forearm
Source: [1].

Moreover, it should also be noted that in the construction of the back we were able to generate ergonomic handles out of pipes, with a natural angle for the wrists – another element mentioned by the users in the conversations (Fig. 3), [1].

We also managed to create an innovative patented solution for simultaneous regulation of the height and width of the armrest and underarm stabilisation with the use of one knob [1].

Seat of the special need stroller – a special stroller-type wheelchair for transporting children. The seat's construction enables mounting it onto: rigid type indoor frame, high-low indoor frame, outdoor frame and light stroller-type frame. The wheelchair might make everyday care easier when transporting people with disabilities that unable walking or sitting and standing correctly.

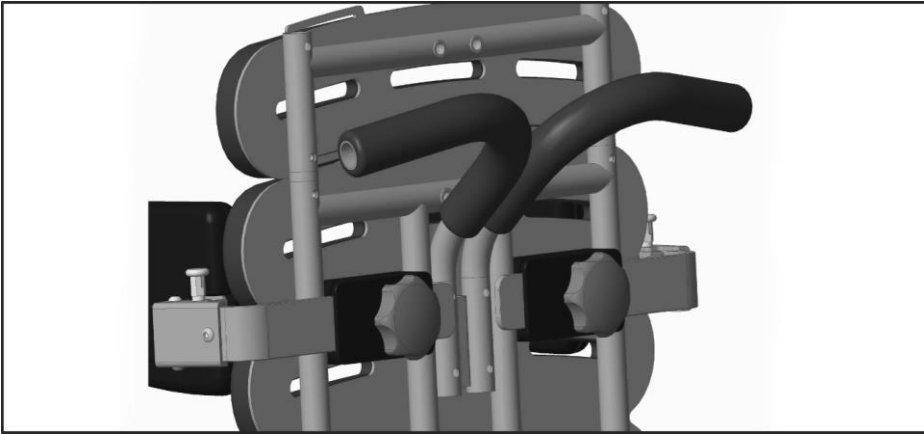


Fig. 3. Handles covered with EVA foam

Source: [1].

The designed seat is made of plastic shaped with the method of injection moulding. A single panel consists of one double element which makes it possible to attach another panel in order to increase the surface of back support. An additional element are covers made of EVA foam which are found on each of the elements emphasising its construction. Due to high costs of production the concept will not be developed by the company for now (Fig. 4).



Fig. 4. Different versions of seats made of plastic additionally covered with soft EVA foam

Source: [1].

Another version of the seat was designed – one made with EVA foam entirely – with this type of seat a joined footboard was suggested, however, finally it was rejected due to difficulties that arose when approaching the child from the front and troublesome positioning of feet [1].

The design team had the most possibilities for modification and working on the attractiveness of the construction while creating new versions of frames for wheelchairs.

Four frames were created and each of them in four versions. The concepts include innovative solutions for covering the wheels and arched connectors for pipes and wheels [1].

Rigid type indoor frame – product intended for orthopaedic seats, equipped with wheels and a mechanism which regulates the height of the vertical axis. It can be used with all types of seats: orthopaedic seat for children, orthopaedic seat for teenagers and the seat of the special needs stroller. The first version of the frame designed for users up to 60 kg intended for the orthopaedic seat for children and the seat of the special needs stroller for children (Fig. 5), [1].



Fig. 5. Sample frame up to 60 kg with an adaptor connecting the pipe with the wheel
Source: [1].

The suggested universal solution for most of the constructions of frames in the place where the frame is connected to the wheels is the so-called “pipe” which eliminates sharp edges that were at the end of the pipes. The solution increases aesthetic as well as utility values by protecting feet and legs of the person pushing the wheelchair against injury. What is more, the proposed solution for the bumper (Fig. 6) can decrease the damage in the direct surroundings of the wheelchair.

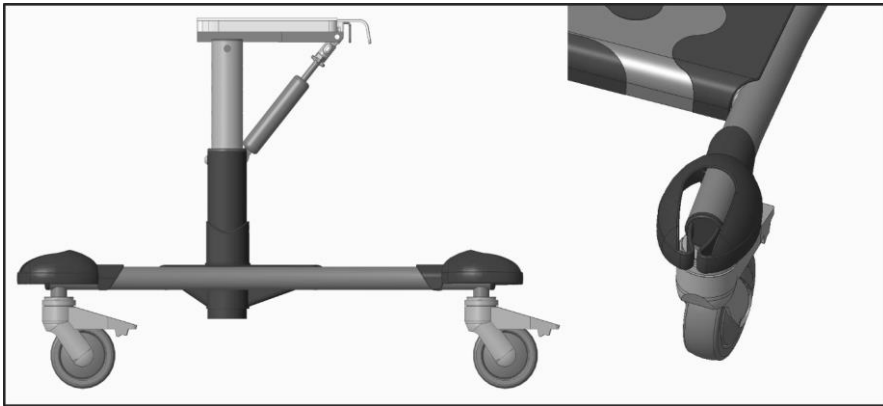


Fig. 6. Sample frame up to 100 kg with a cover-bumper
Source: [1].

The adaptors and the bumpers – covers for the wheels were designed in two versions made of plastic using the method of injection moulding. Additional elements are fitted to the pipes using two screws, due to the requirements of the producer they can carry users of up to 60 and up to 100 kg i.e. the required load [1].

High-low indoor frame – product is intended for orthopaedic seats. It is equipped with a mechanism which allows positioning the child low over the floor. The mechanism which lowers the seat along an arch enables placing the child lower than with a rigid type frame (Fig. 7), [1].

This function is especially important in situations when the disabled child has contact with non-disabled children. Regulating the height of the seat makes it easier to maintain eye contact and enables using the device at tables of various heights. The product is intended for the orthopaedic seat for children and the seat of the special needs stroller. The frame was designed in one size for users up to 60 kg. The construction of the frame is designed in two versions; additionally, new colours were introduced which foreshadow a new aesthetic line for the products of LIW Care Technology. We already know that the graphic concept will be gradually implemented [1].



Fig. 7. Sample high-low indoor frame
Source: [1].

Outdoor frame – product intended for all types of orthopaedic seats. It is equipped with a brake, handle for pushing and big wheels for hard terrain such as stones, forest. Other shapes of the frame aim at providing the user with comfortable semi-reclined position while riding.

Light stroller-type frame – basic frame for the special needs stroller seat. Technical features of the product: foldable into transport size, possibility to mount the seat in different directions (rearward or forward facing), reclining the seat, stopping brake, regulated handle for pushing, big wheels (Fig. 8).



Fig. 8. Light stroller-type frame
Source: [1].

As the construction of the frame is very simple, in this case the team worked on the graphics and designed a dark and light version also choosing fabric for the covers. The concept is a forerunner of the new design philosophy of the company and will be gradually implemented together with modifications of future models [1].

Summary

The design and construction solutions presented in the article are only a small segment of everything that was prepared by the design team. However, these are compromises and their introduction will not require any special financial outlays on the part of the company. Some solutions, such as for example the bag placed under seats in the stroller-type frame – even though very interesting in terms of design – did not interest the producer for the time being and will not be introduced [1].

Detailed research needs to be conducted for the finishing fabric which needs to fulfil incombustibility norms and thus, the natural fabric proposed by the designers (terrycloth) will surely be excluded. Additives or coating the fabric with an incombustible layer might be a solution, but this may destroy the tactile advantages and may be difficult to wash [1].

Another extremely interesting issue is the material filling the seats and backs. It would be advisable to test the multilayer solutions from different natural materials such as cork or coconut, which might minimise the discomfort which appears when a child is sitting for many hours. Properly balanced filling can limit pressure sores.

The presented form of cooperation turned out to be effective and very educating for both sides. We hope that after the cooperation ends the company will be willing to form new ones. Technology and the simplicity of production, but first of all the ergonomic, utility and visual effects of the created solutions definitely indicate that industrial designers coming from design faculties of Academies of Art can act in interdisciplinary teams which lead to introducing new products.

References

- [1] **Siwek, M., Miarka, A., Włodarczyk, M., Jaworski, B., Piechota, P.:** Research and development project titled “Study of orthopaedic seats particularly for children and teenagers with paralysis and paresis (triplegia, tetraplegia, diplegia, hemiplegia or crossed hemiplegia)” by the design team of the Strzemiński Academy of Arts in Lodz.
- [2] www.liwcare.pl – accessed on 24.11.2017.

PRELIMINARY QUESTIONNAIRE SURVEY OF A WHEELCHAIR PROTOTYPE DRIVEN BY A LEVER MECHANISM

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Abstract: Movement of persons with disabilities in manual wheelchairs is associated with everyday inconvenience. Creating modern infrastructure adapted to the needs of persons with disabilities reduces the number of encountered obstacles, but can't solve the problems entirely. It seems obvious that also manual wheelchairs need to be improved in order to increase user's comfort. As an answer to this need a prototype of wheelchair with lever drive was built. Authors of this paper decided to test the functionality of the new design. 12 wheelchair users with various disabilities, who normally practice crossfit on push-rim manual wheelchairs, were asked to carry out a test ride on a given track. Afterwards they were asked to fill previously prepared questionnaire regarding functionality of the prototype wheelchair consisting of 8 questions. More interesting results of the survey demonstrate that 83% of the respondents declare lower physical strain in comparison to push-rim wheelchair and 75% think that the prototype of the lever wheelchair will be advantageous during longer rides. Authors conclude that the prototype lever wheelchair after certain improvements can help in everyday struggle of manual wheelchair users.

Keywords: wheelchair, lever mechanism, prototype, questionnaire survey.

Introduction

Manual wheelchair acts as a mean for medical and social rehabilitation [18]. Its main task is to provide independent locomotion and compensation of lost functions of people with disabilities [17]. It might seem that traditional push rim propulsion and individually adjusted wheelchair parameters allow for efficient mobility and ensure high comfort [9]. However certain factors cause onerousness associated with everyday wheelchair use e.g. direct constant of hand and spinning wheel [4]. In order to solve some of the issues of push rim wheelchairs a prototype of a wheelchair with lever propulsion mechanism was created. In this article there are presented results of a preliminary questionnaire

survey. The survey was aimed at testing whether the proposed propulsion mechanism meets the expectation of users in terms of improving mobility and quality of life. The survey was carried out in a group of potential users.

Methods

Participants

12 active competitors of wheelchair crossfit, some of which took part in world championship in wheelchair crossfit, took part in the test. The subjects had various lower limb impairments but were characterized by high physical fitness. The group was diverse in age, gender and wheelchair driving experience as presented in Table 1.

Table 1. Characteristics of the subjects

No.	Gender [Male/ Female]	Age [years]	Body weight [kg]	Body Height [cm]	Wheelchair driving experience [years]	Disability
1.	M	20	64	170	17	spinal hernia
2.	M	21	80	175	6	spine injury
3.	M	18	85	175	6	ischemia of the spinal rod
4.	M	62	100	180	8.5	paraplegia
5.	M	23	88	204	5	tetraplegia
6.	M	33	50	182	2,5	tetraplegia
7.	M	49	80	176	4	Spine injury
8.	M	27	70	182	7	paraplegia
9.	M	26	66	173	6	paraplegia
10.	M	25	90	186	6	paraplegia
11.	F	18	85	177	3	paraplegia
12.	F	35	59	165	13	paraplegia
Mean $\pm$ SD		29.8 $\pm$ 12.9	76.4 $\pm$ 14.0	178.8 $\pm$ 9.4	7.0 $\pm$ 4.0	

Source: own study.

Prototype of wheelchair with lever mechanism

In the study authors assessed DWI1A wheelchair prototype with lever mechanism presented in Figure 1 which was designed in the project “Lever manual wheelchair for the disabled”.

The prototype DWI1A is equipped with two levers used to propel independently each of the back wheels. Push rims are also attached to the back wheels as in classic wheelchair design. Both modes of ambulation can be used alternatively for riding forward, while reverse riding backwards is possible only with push rim propulsion. Due to one way clutch installed in the lever

mechanism and the manner in which lever and wheel are connected, reverse ride, although carried out with push rims, causes levers to rise from their neutral horizontal position up to the quasi vertical position. When the levers reach this point they stop and interdict any further reverse ride. In other words, when levers are situated almost vertically as demonstrated in Figure 1, the only possible ride direction is forward.



Fig. 1. Wheelchair Prototype DWI1A with lever propulsion mechanism
Source: own study.

The levers are situated between back wheels and seat cushion. This feature provides better ride conditions when using the levers ipso facto hindering push rim position by making it more distant from users sagittal plane. Such design was derived from an assumption, that push rims are to be used only for manoeuvring indoors, riding in balance and generally overcoming obstacles, while lever drive should be used on longer distance, mainly outdoors. The wheelchair frame, seat, footrests, wheels: front (5 inches/0,127 m) and back (24 inches/0,61 m) and other elements are standard and provided by one of the wheelchair manufacturers in Poland. The levers are 0,45 m long, their axis of rotation is positioned 0,074 m behind and 0,051 m over the back wheels' axis of rotation. Propelling the wheelchair with levers is carried out by pushing while pulling is achieved almost without force exertion and is used to bring the levers to their initial, quasi vertical, starting position. The angular range of rotation

of the levers that can be used for propulsion is about 65° . Lever drive has a single, multiplication gear ration of 3, allowing wheelchair user to develop higher velocity in comparison to push rim propulsion. Braking in lever ambulation mode is independent for both back wheels and is achieved by pulling standard bike brake levers, without interruption of the hand-lever contact. Braking is carried out by a band brake mechanism. In the DWI1A prototype design the reaction torque coming from braking the wheelchair is transmitted to the wheelchair frame and not to the wheelchair user. Back wheel camber is 0° and cushion width is 0,40 m. Distance between levers is 0,49 m and distance between push rims is 0,68 m.

Test protocol

Every participant was asked to carry out a test ride consisting of riding 10 m straight, turn back and return in a manner depicted on Figure 2. The ride was repeated 3 times. The persons participating in the study compared the quality of moving on the prototype wheelchair to the quality of movement on that wheelchair, which they use constantly. Before carrying out the test subjects were given verbal instruction on how to use the prototype lever mechanism and were asked to conduct random test rides for 5 minutes.

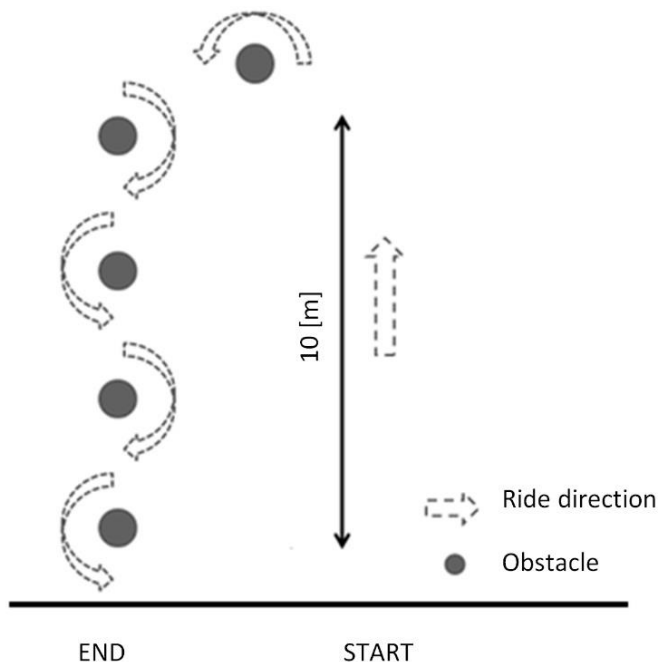


Fig. 2. Scheme of the test rides carried out by the subjects
Source: own study.

Immediately after the tests each subject was asked to answer 8 closed questions regarding:

- effort during ride,
- mass of the prototype,
- wheelchair velocity,
- comfort during ride,
- security during ride,
- possible wheelchair use,
- manoeuvring,
- overcoming obstacles.

Results

The results of the questionnaire survey are presented in Table 2.

Table 2. Results of the survey regarding comparison of prototype lever wheelchair to push rim wheelchair

Question regarding	Response [%]		
Effort during ride	Lesser	The same	
	83	17	
Mass of the prototype	To heavy	Acceptable	
	50	50	
Wheelchair velocity	Higher	Lower	
	83	17	
Comfort during ride	Greater	The same	Lesser
	42	25	33
Safety during ride	42	25	33
Possible wheelchair use	Longer trip	Training	Everyday use
	75	17	8
Manoeuvring	Easier	Requires learning	More difficult
	8	33	59
Better in overcoming obstacles	Ramps up	Ramps down	Curbs
	58	25	17

Source: own study.

Among possible response regarding effort during riding 83% of the subjects answered that it is lesser and 17% that there is no difference in comparison to push rim wheelchair. One half of the subjects stated that the wheelchair is too heavy and the other half that it is acceptable. 83% of subjects responded that wheelchair velocity is higher and 17% lower when compared to push rim

wheelchair. Answers regarding comfort and security were exactly the same: 42% of participants stated that lever wheelchair prototype is safer and more comfortable, 25% saw no difference and 33% regarded push rim wheelchair as safer and more comfortable. 75% of respondents saw possible wheelchair use in longer trips, 17% in training and 8% everyday use. Manoeuvring with lever wheelchair prototype was easier only for 8% of participants, 33% said that it required learning and 59% regarded it as more difficult. According to 58% of respondents the prototype can be advantageous in overcoming ramps when riding up, 25% when riding down and 17% of the subjects believe that the wheelchair prototype can be better for overcoming curbs.

Discussion

Limitations of the study

In the questionnaire survey took part only 12 participants with various impairments therefore acquired results should be treated as preliminary and allowing for very immature assessment of the wheelchair prototype. Also before the survey the subjects could familiarize with the wheelchair for a very short time. It is probable that persons with longer experience of driving lever wheelchair prototype would answer differently to presented questions.

Results of the questionnaire survey

Authors decided to divide the results of the survey into 3 groups: optimistic, neutral and pessimistic.

In the optimistic group of the results the response to question regarding effort during ride seems to take the first place. 10 out of 12 subjects saw that it is lesser when compared to push rim wheelchair. The result becomes even more optimistic when considering the fact, that participants had almost no driving experience with the lever drive mechanism and therefore were unable to use it optimally.

Authors find optimistic also the response to question regarding wheelchair mass where half of the subjects found it acceptable. This is because the wheelchair mass will be lower when the wheelchair will become more developed and introduced to the market. Therefore it seems probable that the percentage of users that could accept the new wheelchair will grow.

83% of subjects notice that the lever wheelchair allows for faster riding which is an advantage. Probably this feature is connected with expectations of the respondents expressed in answers to the question regarding possible wheelchair use, where 75% saw the wheelchair prototype good for longer trips.

Authors also find optimistic the identical response to questions regarding safety and comfort, where 42% of participants stated that lever wheelchair

prototype is safer and more comfortable, 25% saw no difference and 33% regarded push rim wheelchair as safer and more comfortable. It should be underlined that the tested wheelchair had certain geometry and therefore was not adapted perfectly to all of the subjects. For this reason already during tests some of the subjects with greater body weight declared lack of comfort because of improper wheelchair width. Also the longitudinal inclination of the wheelchair frame was not proper for some of the subjects suffering from tetraplegia. For some also the backrest height was improper. Taken into consideration the given facts it seems very optimistic that 67% found the tested wheelchair more or the same comfortable and safe in comparison to their own, custom designed push rim wheelchairs.

The answers to question regarding overcoming obstacles seem to be neutral. 7 out of 12 respondents found the lever wheelchair prototype for overcoming slopes when riding up, 3 out of 12 when riding down and 2 persons stated that overcoming curbs by the lever wheelchair may be convenient. However, since there were no obstacles like this on the test ride, authors approach these answers with a distance.

Answers regarding manoeuvrability seem to be pessimistic. Most of the subjects found manoeuvring more difficult with the lever wheelchair than classic wheelchair. Probably that is also the reason why only 1 out of 12 persons found the lever wheelchair suitable for everyday use. This responses may suggest, that the tested lever mechanism cannot substitute push rim propulsion when it comes to manoeuvring.

Comparison of results to findings of other authors

In many papers it is concluded that improving manual wheelchairs is necessary to improve the quality of life of people with disabilities [3, 12, 5, 16]. The concept of lever drive for wheelchairs is one of the ideas to achieve this goal from the twentieth century. The newer ideas regarding adding levers to a wheelchair often tackle the issues of assembly and disassembly of lever mechanism [12, 7, 1, 19]. The wheelchair assessed in this study was a preliminary prototype where these issues were not yet addressed. The proposed changes in design of propulsion mechanism aimed to provide high ride comfort and mobility.

Research regarding lever wheelchairs also focuses on the physical condition of wheelchair users. Some authors state that usage of lever wheelchair instead of classic wheelchair should be recommended since it can reduce back and wrist pain [20, 10, 15]. Also it was said that using lever propulsion mechanism results in 70% less load on arms in comparison to push rim wheelchair [14]. Since trunk movement is not that much important in lever wheelchair propulsion as it is in case of push rims, patients with limited control of trunk movement should be able to more easily keep trunk stable when using lever mechanism [6]. It is also underlined that efficiency and velocity of riding on lever wheelchair is

favourable [8], also because the position of human upper limbs during propulsion is more natural [11]. To the above mentioned advantages of lever wheelchairs one more important aspect is added: social rehabilitation. It is said that using lever wheelchair helps building the sense of independence and allows for expanding social life [2]. Findings of this paper regarding ride velocity and efficiency are in compliance to these presented in [8], however since this was only a preliminary study the issues discussed by other authors were not addressed. What can be added from here presented results is the general feeling of safety and comfort of lever wheelchair users.

Summary

In consideration of the results of preliminary questionnaire survey it can be concluded that the tested wheelchair prototype with lever mechanism has the potential to provide the possibility of carrying out faster, safer and more comfortable rides during longer trips and with lesser effort when compared to push rim wheelchair. However to ensure success in introduction of the lever drive concept to the market it seems inevitable to address the issues of manoeuvring, wheelchair mass and overcoming obstacles like curbs.

Acknowledgement

The research was carried out in cooperation of Warsaw University of Technology and Józef Piłsudski University of Physical Education in Warsaw. The tested wheelchair prototype DWI1A was designed in a project "Lever wheelchairs for the disabled" ref. num. INNOTECH-K3/IN3/52/226230/NCBR/14.

References

- [1] **Agarwal, S., Gautam, S.:** Analysis and optimization of lever propelled wheelchair. Proceedings of the International Conference on Innovative Applications of Computational Intelligence on Power, Energy and Controls with Their Impact on Humanity, CIPECH 2014, IEEE. 2014, 433-440.
- [2] **Cooper, R.A., De Luigi, A.J.:** Adaptive Sports Technology and Biomechanics: Wheelchairs. PM&R. 6(8), 2014, 31-39.
- [3] **Flemmer, C.L., Flemmer, R.C.:** A review of manual wheelchairs. Disability and Rehabilitation: Assistive Technology. 11(3), 2016, 177-187.
- [4] **Grabarek, I., Choromański, W.:** Selected issues for the design of innovative means of transport adapted to people with reduced mobility. Wybrane zagadnienia projektowania innowacyjnych środków transportu dostosowanych do osób o ograniczonej sprawności ruchowej. Zeszyty Naukowe Politechniki Śląskiej 2014.
- [5] **Jenkins, A., Gooch, S.D., Theallier, D., Dunn, J.:** Analysis of a Lever-Driven Wheelchair Prototype and the Correlation between Static Push Force and Wheelchair Performance. IFAC Proceedings Volumes. 47(3), 2014, 9895-9900.

- [6] **Kloosterman, M.G.M., Buurke, J.H., Schaake, L., Van der Woude, L.H.V., Rietman, J.S.:** Exploration of shoulder load during hand-rim wheelchair start-up with and without power-assisted propulsion in experienced wheelchair users. *Clinical Biomechanics*. May 34, 2016, 1-6.
- [7] **Lui, J., MacGillivray, M.K., Sheel, A.W., Jeyasurya, J., Sadeghi, M., Sawatzky, B.J.:** Mechanical efficiency of two commercial lever-propulsion mechanisms for manual wheelchair locomotion. *Journal of rehabilitation research and development*. 50(10), 2013, 1363-1372.
- [8] **Lui, J., Macgillivray, M.K., Sheel, A.W., Jeyasurya, J., Sadeghi, M., Sawatzky, B.J.:** Mechanical efficiency of two commercial lever-propulsion mechanisms for manual wheelchair locomotion. *J Rehabil Res Dev*. 50(10), 2014, 1363-1372.
- [9] **Mikołajewska, E.:** The choice of wheelchairs for disabled people in Polish and foreign scientific research Dobór wózków dla niepełnosprawnych w polskich i zagranicznych badaniach naukowych, *Annales Academiae Medicae Silesiensis* 2013.
- [10] **Requejo, P.S., Lee, S.E., Mulroy, S.J., Haubert, L.L., Bontrager, E.L., Gronley, J.K. et al.:** Shoulder muscular demand during lever-activated vs pushrim wheelchair propulsion in persons with spinal cord injury. *The journal of spinal cord medicine*. 31(5), 2008, 568-577.
- [11] **Requejo, P., Lee, S.E.J., Mpt, L.H., Ms, E.B., Mulroy, S., Therapy, P. et al.:** Shoulder Joint Load during Lever Wheelchair Propulsion in Individuals with SCI. 28(3):20732, 2005.
- [12] **Rifai Sarraj, A., Massarelli, R., Rigal, F., Moussa, E., Jacob, C., Fazah, A. et al.:** Evaluation of a wheelchair prototype with non-conventional, manual propulsion. *Annals of Physical and Rehabilitation Medicine*. Elsevier Masson SAS;53(2), 2010, 105-117.
- [13] **Sarraj, A.R., Massarelli, R.:** Design history and advantages of a new lever-propelled wheelchair prototype. *International Journal of Advanced Robotic Systems*. 8(3), 2011, 12-21.
- [14] **Sasaki, M., Stefanov, D., Ota, Y., Miura, H., Nakayama, A.:** Shoulder joint contact force during lever-propelled wheelchair propulsion. *ROBOMECH Journal*. 2(1), 2015, 13.
- [15] **Ślowik, J.S., McNitt-Gray, J.L., Requejo, P.S., Mulroy, S.J., Neptune, R.R.:** Compensatory strategies during manual wheelchair propulsion in response to weakness in individual muscle groups: A simulation study. *Clinical Biomechanics*. Elsevier Ltd;33, 2016, 34-41.
- [16] **Smith, B.W., Zondervan, D.K., Lord, T.J., Chan, V., Reinkensmeyer, D.J.:** Feasibility of a bimanual, lever-driven wheelchair for people with severe arm impairment after stroke. 2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2014, 5292-5295.
- [17] **Sydor, M., Zabłocki, M.:** Some problems concerning wheelchair selection and configuration with manual drive Wybrane problemy doboru i konfiguracji wózka inwalidzkiego z napędem ręcznym. *Fizjoterapia Polska* 2006.
- [18] **Sydor, N., Krauss, A. and Krauss, K.:** Risk analysis for operation operation of active wheelchairs in non-urban settings, *Annals of Agricultural and Environmental Medicine*, Vol. 24, No. 3, 2017, 532-536.
- [19] **William, J., Smurthwaite, J.:** Manually driven wheelchair. US Patent 7520519. 2009.

- [20] **Zukowski, L.A., Roper, J.A., Shechtman, O., Otzel, D.M., Hovis, P.W., Tillman, M.D.:** Wheelchair ergonomic hand drive mechanism use improves wrist mechanics associated with carpal tunnel syndrome. *Journal of rehabilitation research and development*. 51(10), 2014, 1515-1524.

BLUMIL – SMART ELECTRIC WHEELCHAIR THAT OVERCOMES OBSTACLES

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Abstract: The purpose of this article is to present the specific situation of different wheelchairs users and their needs. There are numerous different disabilities that effect people of different ages. On top of that each person has a different physique. Additionally, each person has different needs and ambitions. If we join all of the above factors, we have an almost infinite number of combinations. This presents a huge challenge for wheelchair manufacturers. What makes the situation additionally harder is the financial status of each person, as some solutions, especially those tailor made, can end up being very pricey. Therefore, there are several main types of wheelchairs on the market that try to cater for their needs. The aim of this article is to present main types of users and wheelchairs that are used by them. We also present in detail the Blumil – a wheelchair that attempts to be most diverse and universal, using unique new technologies.

Keywords: wheelchair, wheelchair users, disability, wheelchair types, wheelchair accessories, Blumil.

Introduction

The purpose of this article is to present the specific situation of different wheelchairs users and their needs. There are numerous different disabilities that effect people of different ages. Therefore, there are several main types of wheelchairs on the market that try to cater for their needs.

The numbers of wheelchair users differ around the world, but on average their numbers in each country do not exceed 2% of the entire population (Table 1). In 2010 more than four million wheelchairs were produced and their total retail value reached 3 billion dollars. The number of sold wheelchairs is largely influenced by the economic situation of a given country. The wealthier the country, the higher number of sold wheelchairs. Japan, Great Britain, and the USA are leaders among the countries with the highest numbers of wheelchair users. Each year for every 10 000 people, 59 wheelchairs are sold in Japan, 44 in Great Britain and 36 in the USA.

Table 1. Wheelchair users in the world

COUNTRY	Number of wheelchair Users	% of Population	Wheelchairs bought for every 10 000 people
USA	3 300 000,00	1,10%	36
Poland	565 000,00	1,50%	No Information
France	360 000,00	0,60%	15-17
Germany	1 560 000,00	1,90%	15-17

Source: own study based on [2].

The reason for using wheelchairs are various. They very often are related to geriatric diseases (mainly joint diseases), post-traumatic disabilities, incurable diseases and birth defects. There are 3 main groups of wheelchair users.

- People who are completely dependent on wheelchairs; they are not able to walk.
 - Self-reliant wheelchair users, who use active wheelchairs; they lead an independent life.
 - People with limited mobility – they use electric wheelchairs or require assistance if they use manual wheelchairs.
 - People with no mobility – they need constant assistance in everyday life.
- People who are partly dependent on wheelchairs on a long-term basis; their ability to walk is limited.
 - People with an alternating ability to walk – it depends on their health; a wheelchair can be necessary for some situations.
 - People who can walk short distances; heavily dependent on a wheelchair, it is necessary for everyday life.
- People with a limited mobility on a short-term basis – after injuries, the period of illness.

In general, wheelchair users' mobility and reasons behind limited mobility are various, and therefore there are different types of wheelchairs to fit different needs and preferences. The most popular ones are manual wheelchairs (42,3% of all wheelchairs), passive manual wheelchairs (28,2% of all wheelchairs) and active wheelchairs (6,7% of all wheelchairs).

Main wheelchair types and accessories

Manual wheelchairs

Manual wheelchairs are mostly powered by your hands strength [1]. They are therefore generally used by people, whose hands movements are not

limited [3]. They are, by far, the most popular category of wheelchairs on the market. Their characteristics are small size and manoeuvrability.

Electric wheelchairs

There are many types of electric wheelchairs. They differ in many aspects: both visual and technical. There are wheelchairs, which have from 4 to 6 wheels. They're considerably heavy and they are not always suitable for all terrain adventures, though most of them are equipped to all-terrain escapades. They often have drive wheels in the front and are said to be easily configured to users' needs. They are often controlled by a joystick, which steers the vehicle.

Beach wheelchairs

Beach wheelchairs often have three wheels. They're designed to navigate easily on the sandy surface. Depending on the brand and needs' of a user, there are quite a few models to choose from. They can be either pushed by others or self-propelled, depending on one's abilities.

Hand Bikes attached to wheelchairs

Coming back to the main subject of the post – aside from different types of wheelchairs, there are many wheelchair accessories on the market. What's an interesting example of that? Handbikes!

Designed for outdoors fun, hand bikes are quite a nice option for manual wheelchair users. If you attach a handbike to your manual wheelchair, your mobility's higher and you can successfully explore the countryside. With the handbike, the wheelchair is not very compact, but definitely suitable for off-road trips.

Pros and cons of different types of wheelchairs

Each type of wheelchair has its strong and weak spots. Manual wheelchairs, for example, are rather small and maneuverable, but they are not suitable for navigating in a difficult terrain, and their outreach is limited. Electric wheelchairs are suitable for all terrains, but they are big, difficult to maneuver and often lacking in design. How does Blumil electric wheelchair compare with most of the manual and electric wheelchairs? It is presented in Table 2.

Table 2. Blumil electric wheelchair. Comparison to different wheelchairs

why is it better than a manual wheelchair	why is it better than an electric wheelchair	why is it better than other segway adaptations
ease on all surfaces (pavement, grass, gravel, sand, snow, ice)		
ease downhill/uphill (over 30% inclines)		
	travels through standard doorways and into elevators, move from indoors to outdoors in a snap	
you will not get dirty (going through rain, mud, snow)		
travel at high speeds (20 km/h)		
	light	
		heavy duty
		easy installation (4 screws)
		quick delivery (within a month)
		different sizes (perfect adjustment for different phsiques)
		range of colors
		low price
		simple and quick parking mechanism
		no additional batteries
		easy adjustment for different disabilities
	attractive design	

Source: own study.

The Perfect Wheelchair

For years people have been trying to create the perfect wheelchair. What would it be like? There are some of its features listed below [4]:

- It should be customised to each wheelchair user's needs.
- It should be catered to all-year usage.
- It should be easy to assemble and disassemble for comfortable transport.
- It should be easy to navigate; using a wheelchair should not be tiring.
- It should fit in limited space, for example, door frames.
- It should be equipped with an electric drive to support the muscle power in the changing terrain conditions.

- Its price should be lower than the price of electric wheelchairs currently available on the market.

Blumil electric wheelchair

The history of Blumil (Fig. 1), the electric wheelchair, started several years ago. I was utterly disappointed with the wheelchair market. It seemed to have a lot on offer, but nothing that would completely cater to my needs. I wanted to enjoy the mountains, stroll along the sandy beaches and breath in the winter air in snowy parks. All I needed was to experience freedom. The market didn't seem to support my idea. You could either get an enormous electric wheelchair that would fail every city test or give up your travel aspirations. Producing something relatively light, both indoors and outdoors-friendly? Well, that was a new idea. I was never the one to shy away from the challenge, so I took matters into my own hands. Since there was no wheelchair of my dreams. I would create it. That's how everything began – necessity is the mother of invention, as they say.

Ideas are beautiful, but until they are put into action, they are just that: ideas. I knew I needed to make Blumil reality, so I kept looking for somebody who would help me. I was lucky to have met wonderful people, whose passion and knowledge, brought Blumil into life. At first, it was supposed to be my private vehicle, a project that would enhance the quality of my life. As soon as I started to use it, though, I realized it was truly life-changing. It helped me to experience more, and I wanted others to discover the freedom I found. After 5 years of work, Blumil was no longer just an idea of mine – it was the reality. Since 2015 Blumil's part of the wheelchair market scene, and we constantly work to improve it – for the better future and the greater freedom. Since Blumil is an electric wheelchair based on Segway, Airwheel or Ninebot construction, it is very intuitive and easy to steer. Its relatively small size and weight make it perfect for both city and outdoors travel. The lightest model is 38 kilograms, which is the reason why it is so easy to navigate on Blumil. Two wheeled, equipped with gyroscopes and onboard computer, Blumil electric wheelchair has changed my life in profound ways. It allowed me to explore beautiful, hilly Lisbon, soak up the atmosphere in Barcelona and use public transport in busy, vibrant Warsaw. I've visited numerous places all around the world and to be honest, Blumil has made all the difference in my traveling experience. You can easily transport this wheelchair, it can handle about every surface and is small enough to fit in a very limited space. Ultimately, Blumil and freedom go together very well – just like intended.



Fig. 1. Blumil S5 on snow
Source: [5].

Blumil is an all-terrain, off-road electric wheelchair. It is different to most of the wheelchairs on the market, thanks to its size and weight. While a vast majority of wheelchairs are heavy and big, Blumil's considerably light and small. It easily fits in narrow passages and is well-suited for both cities and the countryside. It's based on the Segway technology and thanks to its small size, it's compact and easy to navigate. You can easily control it yourself: no joysticks are needed. It's fast, too: 15-20 kilometers per hour is the speed it can go into if you wish to race through the city.

Actually, since I have Blumil my friends are the ones who stay behind. Before, I would have some problems navigating through busy cities, but with Blumil I am always ahead of everybody. The first time somebody was able to keep up with my pace was in Budapest – I took part in the Segway tour and my guide and I were the fastest guys in the town. Possibly!

Types of Blumil

Blumil, just like other wheelchairs, has many models! Blumil S3 (Fig. 2) is a “city dweller” – perfect for park alleys, lawns and even for rainy days when everything's a bit too slippery.



Fig. 2. Blumil S3
Source: [5].



Fig. 3. Blumil x2
Source: [5].

On the other hand, the model x2 “Extreme adventure” (Fig. 3) will do perfectly well in every type of terrain: from cobblestone, sand to sand – to mention just a few.

Each model has specific features, which make it suitable for various types of terrain. They are all listed in the tables below (Table 3 and Table 4).

Table 3. Blumil model comparison. Surface

Surface	S3 City dweller	S5 Ultimate freedom	i2 Incredible range and comfort	x2 Extreme adventure
Cobblestone	X	✓	✓	✓
Park alleys	✓	✓	✓	✓
Lawn	✓	✓	✓	✓
Sand	X	✓	✓	✓
Rain	✓	✓	✓	✓
Snow or mud	X	✓	✓	✓

Source: own study.

Table 4. Blumil model comparison. Parameters

Parameters	S3 City dweller	S5 Ultimate freedom	i2 Incredible range and comfort	x2 Extreme adventure
Range (kilometers/miles)	25 / 15,5	30 / 18,6	38 / 23,6	19 / 11,8
Max. speed (kph/mpg)	15 / 9,3	15 / 9,3	20 / 12,4	20 / 12,4
Weight (kg/lb)	37,5 / 82,6	49 / 108	63 / 139	70 / 154
Width (centimeters/inch)	64 / 25	77 / 30	63 / 25	89 / 31

Source: own study.

There are a few companies, who produce Segway-based electric wheelchairs. Their prices differ: mainly because of the design and the parking mechanism. The parking mechanism is, by far, the most difficult element in creating and designing when it comes to Segway-based wheelchairs. As Segway is two-wheeled so a stabilizing mechanism is crucial to safe usage of a Segway-based wheelchair. In addition, the Segway has built-in sensors that respond to the pressure of the person if the person's standing. To turn the machine on the sensor can't be loaded. In contrast, it must be loaded to operate. In addition to the stabilization function, the parking mechanism must also press the sensors in the right moments. Due to the complexity of the motion, creating such

a mechanism is very difficult. The easiest way to do this is by using electrical systems. This solution, sadly, has a lot of disadvantages listed below:

- We need to charge an additional battery.
- The extra battery is protected from moisture as well as the Segway battery, so it is very like to fail.
- The weight of the whole device increases.
- The cost of air transport increases, due to tighter requirements regarding the transport of batteries.
- Each battery has a certain usage expectancy - after some time you have to buy a new one.
- Unlocking and locking the entire mechanism takes a lot longer than in the manual mechanism.
- Higher cost.

In Europe, Genny electric wheelchairs are the most popular option as of now. It costs more than 21 000 euros, and due to its high price, it is not widely accessible to the vast number of people. Ally Chair is another leading company on the market. It is based in USA and supports American war veterans with the foundation Segs4vets. The foundation recently bought the company. They don't have any dealers in the USA or worldwide. There are a few other companies, but they mainly operate on their national markets due to high costs of shipping the product internationally.

Summary

The quest for a perfect wheelchair has started many years, and so far, perfection is yet to be reached. Each and every solution has its advantages and disadvantages and it is difficult to create something that would cater to everybody's needs. Light wheelchairs are often extremely expensive, cheaper ones – heavy and difficult to navigate. With Blumil, I aim to help others experience freedom and hopefully move closer to the definition of a perfect wheelchair. The best is yet to come, and hopefully a long-time dream will become the reality soon. At this stage I'm planning to develop a new versions of Blumil that will be suitable for the elderly and for children. To do so I will focus more on user's ergonomics to provide optimum riding position and comfort.

References

- [1] **Brooks, L.L., Wertsch, J.J., Duthie, E.H. Jr.:** Use of devices for mobility by the elderly. *Wisconsin Medical Journal* 93(1), 1994, 16-20.
- [2] **McKe, C.:** A market-based approach to inclusive mobility. Report. Institute of Transport Studies, Monash University 2010.

- [3] **Sapey, B., Stewart, J., Donaldson, G.:** The social implications of Increases in Wheelchair Use. Report: Department of Applied Social Science. Lancaster University 2004.
- [4] Project wheelchair: Neukonzeptionierung des Rollstuhlprinzips 2009.
- [5] www.blumil.com.

DESIGNING HANDLES OF HAND TOOLS IN THE ASPECT OF COMFORT AND SAFETY

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Abstract: The article describes the issues related to requirements that has to be met by handles of hand tools. The analysis of literature of the subject matter related to designing hand tools in connection with anthropometric features of a person was carried out. An attempt to present certain problems related to designing handles of hand tools was made in the article. In the body of the article, the present state of knowledge in the subject of designing hand tools was presented and specific examples were provided. Furthermore, the issues related to designing hand tools for left-handed people were signaled.

Keywords: occupational safety, anthropometry, hand tools.

Introduction

In a number of cases, using hand tools may lead to accidents. An incorrectly selected tool may also cause damage to a treated element. Often, when selecting hand tools, the main criterion is its price, suitability for a particular activity and safety. At present, when choosing tools, ergonomics of such a tool is the criterion.

Designing hand tools

An uncomplicated process, an action being performed, visible and obvious functionality and theoretically simple construction make the process of creating hand tools and customization to individual seem simple and undemanding. Contemporary market and greater consumer awareness require from manufacturers greater engagement in designing and production. In the light of the literature of the subject as well as from our own experience it can be stated that the research on functionality and safety of using tools complement realities, and not only efficiency. Design and development of new construction, modern materials used to build tools affect the ease of use, functionality, safety and even health of an employee.

Continuous development of new technologies, materials engineering or industrial design imposes on the manufacturers of tools increasingly higher

requirements for professional users and affects greater user's expectations related to hand tools. Manufacturers of hand tools are required to implement specialized research procedures, where the acquired knowledge is used, which directly corresponds to the market requirements. The versatility of tools designed for individual application such as when working in a car workshop is not enough – on the contrary, improperly selected may lead to extensive and costly damages – regardless of whether we talk about the health of a user or the condition of property entrusted.

Designing professional hand tools requires assessment and analysis of the work environment. It is important to predict how often, how long and whether repetitive actions will be performed using a particular tool, and how much effort you will need to be able to work effectively, and thus how doing a particular job translates into workpieces and a user's comfort. Using hand tools also requires an assessment of the work environment of the tool being used and who works on it every day, which translates into work efficiency with minimal employee's effort. In many cases, the work with the use of manual tools carried out by an employee requires the same actions, and only working conditions may change, and thus the right choice for individual functionality needs undoubtedly translates into efficiency, quality and safety – not only for the user but also the tools themselves. In designing, typical dimensions and possible ranges of body movements definitely ought to be considered. Figure 1 shows optimum ranges of movement of body parts. The provided angular traffic ranges include values defined as comfortable or easy, taking into account the possibilities of over 95% of the total population (male and female) [4].

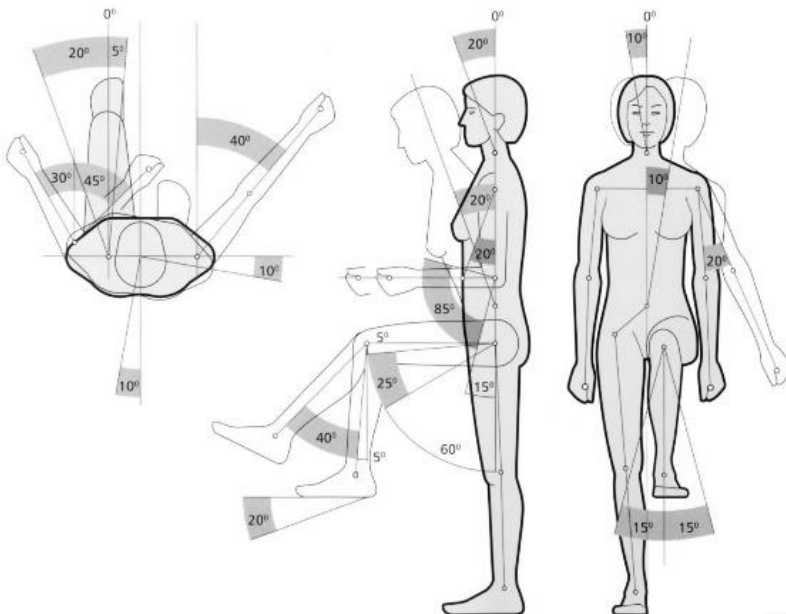


Fig. 1. Ranges of movement of body parts
Source: [4, 12].

High workmanship is influenced by working parts, ignoring properties and material differences may cause damage of workpieces and, in the worst case, more serious faults. Awareness of diversity is a key to ergonomic and safe designing of tools. An incorrectly designed screwdriver can negatively affect not only functionality of the tool itself but also affect a user's health, starting from skin abrasion on a hand or corns, and ending up with joints overload of wrists and elbows, and tired muscles of a forearm, an arm shoulder and a shoulder. A well-chosen hilt should ensure maximum use of screwdrivers with the possibility of large torques. In practice, development of hand tools should take into account individual characteristics of employees as well as characteristics of materials intended to produce tools dedicated to specific tasks. Appropriate prototyping of a hilt that fits the size of a user's hand directly affects comfort and safety of his or her work. For example, modern hammers are usually made of steel, rubber, plastic or wood. The faces of steel hammers (locksmith's hammers, claw hammers, carpenter's hammers) are tempered zonally, which increases the strength of a tool. The zones of the ending of the face being hardened are places which are directly exposed to damage during work. Due to the structure of a tool, the closer it is to the centre of a hammer face, the lower the degree of hardening. Thanks to that, the steel in the part of a hammer face which is connected to the handle is more elastic. This makes that the whole hammer face is more resistant to cracks. An important spot of a hammer is the place of connecting the face with the handle. In case of hammers with a wooden handle, the most common way of joining is the so-called double wedging. One wooden wedge and one or two steel wedges are used then. In case of hammers with modern fibreglass handles, stable and durable joints are obtained by using suitable adhesives. In case of steel handles, the most effective connection with a hammer face is provided with the use of expansion pin going through both parts. Hammers with rubber handles are usually connected with a handle using a special inserted steel pin. An interesting solution is to use handles with a structure similar to a tuning fork. Covering the hilt with a suitable polymer causes that, during the work, the vibrations do not pass directly to the employee's hand and the appropriate shape and material of the handle ensure a secure but comfortable and safe grip. In case of hammers with a wooden handle, hickory wood is used. It is characterized by high elasticity so that the vibrations generated during work are reduced. This causes partial suppression of the vibrations transferred to a hand. In case of hammers with handles made of fibreglass and metal, the technology used is a bit more complicated. In order to ensure a suitable solution, handles made of soft plastic (possibly from a combination of several materials of different hardness) are used. These types of handles are sometimes called anti-shock due to high absorption and reduction of vibrations. The high plasticity of materials used for this purpose causes them to be properly shaped and fit perfectly in the hand.

The important question is whether an operator uses his or her right or left hand, and this should not matter from a practical point of view. In fact, not all tools are suitable for work for right- and left-handed people. To a large extent,

hand tools are produced for right-handed people, which, in case of left-handed people, forces a non-ergonomic way of work. Appropriately profiled geometry of a tool improves, for example, the point of view and, as in case of "normal" scissors, gives a specific direction of cutting from a constructional point of view. Therefore, the best material cutting and optimum results are obtained using correct cutting direction. With the use of modern materials and well-shaped blades, left-handed people can work in a safe and "ergonomic" way, which translates into increased visibility and widens the working area.

In practice, a well-designed tool described as "ergonomic" may turn out to be completely inadequate (non-economic or even dangerous) for a given user or the way he or she performs the task [2]. Therefore, the ergonomics of tools is a specific potential for the tool to be protected against injury and overloading, provide comfort, efficiency and noticeability [1]. The ergonomic quality of a hand tool is influenced by many factors including:

- fitting handles to anthropometric features and dimensions and structure of a tool as well as shape of a handle,
- positioning a handle in relation to the tool or work surface,
- material of a handle,
- structure of a tool that forces a specific position of a worker's body and a tool, and movement of forces,
- an employee (individual characteristics) and a process (work, environment, conditions, etc.),
- reduction of mass,
- transparency of a reading of physical quantities,
- versatility,
- consumer preferences; when choosing a tool, employees /employers rely on perceived attributes of a product, which requires an analysis of fitting for each person individually.

In majority of the aforementioned, such an approach cannot be fully implemented in case of industrial goods produced in a serial manner as it affects the cost of production. The operator's hand is an obvious extension of a hand tool creating together a biomechanism that is capable of performing a specific work or activity. With regard to dimensional fitting of tools, due to a wide range of anthropometric features of the population of users of different technical objects, in design practice, they are matched to threshold (boundary) characteristics expressed in centile characteristics.

In case of hand tools such as shovels, axes and other tools where not all parts of the body must be taken into account, dimensional features may be important while designing them:

- elbow height in standing position,
- bottom reach (the height from the ground when the upper limb is lowered along the trunk),
- diameter of the forcible handle,
- width of the hand.

These features are indicative in relation to the mechanics of movement segments. The latest anthropometric atlases of the Polish population contain the values of threshold dimensions for the above-mentioned characteristics. In practice, the top threshold values – 95C of men and the bottom threshold values – 5C of women are: 5, 50 and 95 centiles.

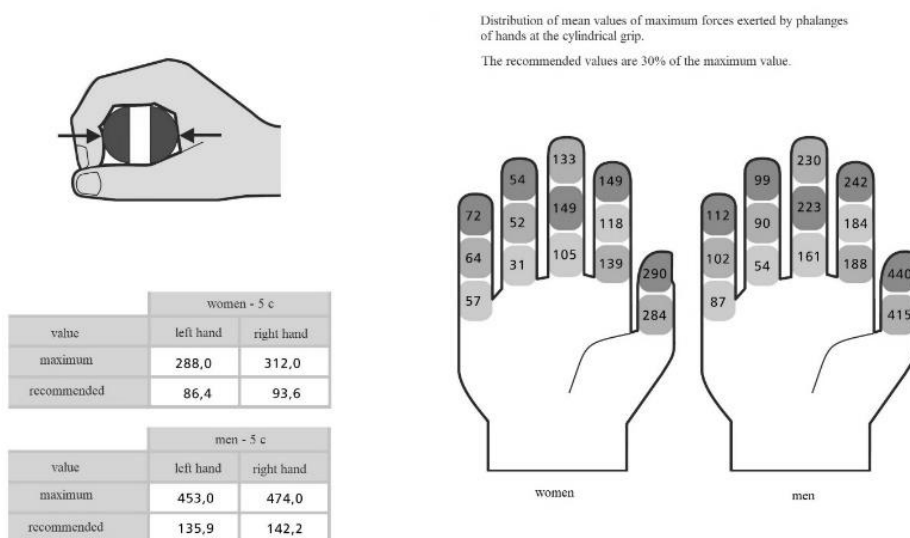
European population data covering the anthropometric dimensions of European countries for the total population of men and women are presented in EN-547-3, EN-349, EN-294, EN/ISO 15537. Numbers of selected features are presented according to EN 979 classification [4].

Dimensions of height, length, width and depth for each centile are given in millimetres. It is assumed that a centile of p row is such a C_p value for which $p\%$ of the population has a value of a given characteristic that is higher, while the remainder of the population ($100\% - p$) lower than C_p . The bottom (5C) and top (95C) centiles are threshold dimensions. Centile 95 determines maximum values that are not exceeded by 95% of population, and centile 5 – minimum values that are not reached by 5% of population [4].

In further designing of hand tools, there is to estimate the distribution of forces in standing and sitting positions as well as pressure of a hand and the distribution of force on phalanges. Knowing these parameters is crucial and requires considering typical values.

Table 1 shows clamping force of a hand and force distribution on phalanges. Tables 2 and 3 show force distribution of the upper limb in the standing position, whilst Table 5 shows forces distribution of the upper limb in the sitting position [4].

Table 1. Clamping force of a hand and force distribution on phalanges [4]



Source: [4, 12].

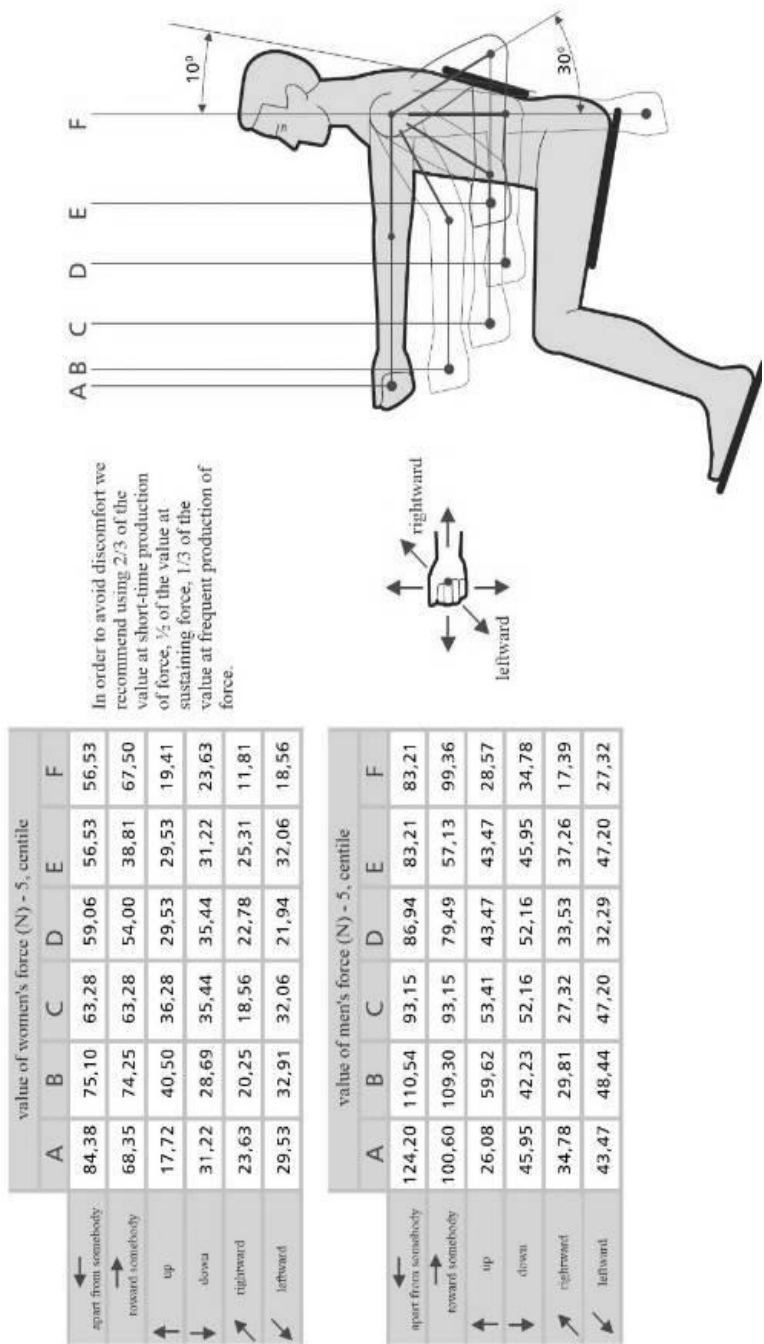
Table 2. Forces distribution of upper limb in a standing position

value of women's force (N) - 5. percentile				value of men's force (N) - 5. percentile			
A	120°	B	90°	C	60°	D	30°
1	61,67	77,38	61,67	86,55	108,60	86,55	97,47
2	46,55	67,84	57,70	65,32	95,21	80,99	86,55
3	30,83	57,70	54,33	43,28	80,99	76,25	76,25
1	50,36	56,09	59,91	70,68	78,72	84,08	92,11
2	43,76	50,36	57,70	61,41	70,68	80,99	76,25
3	36,85	44,34	54,33	51,72	62,23	76,25	62,23
1	36,85	34,80	54,33	51,72	48,84	76,25	110,87
2	46,55	50,36	77,38	65,32	70,68	108,60	138,48
3	54,33	65,63	96,47	76,25	92,11	135,39	170,63
1	79,00	63,87	57,70	110,87	89,64	80,99	86,55
2	112,03	77,38	63,87	157,23	108,60	89,64	97,47
3	146,83	108,21	67,84	206,07	151,88	95,21	105,51
1	40,38	38,62	42,58	56,67	54,20	59,76	56,67
2	42,58	48,16	52,13	59,76	67,59	73,16	62,23
3	46,55	57,70	63,87	65,32	80,99	89,64	67,59
1	46,55	46,99	50,36	65,32	65,94	70,68	70,68
2	57,70	64,31	65,63	80,99	90,26	92,11	80,99
3	67,84	81,20	81,20	95,21	113,96	113,96	89,64

1 - 100% of reach 2 - 75 % of reach 3 - 50 % of reach

Source: [4, 12].

Table 3. Forces distribution of upper limb in a sitting position



Designing hand tools in the aspect of dimensions of a handle

When working with hand tools, the important aspect is a structure of handles of tools, which directly affects comfort of use and safety of an employee (Fig. 2÷3). Poorly designed handle of a tool, which is too short will cause pressure on parts of a hand, too wide will cause difficulty in keeping the tool and handling while performing actions. Another negative effect will be slipping of the tool from hand which can cause injury or damage to the property entrusted. The dimensions of hands are directly related to gender or race. Motor capabilities are related to age of an operator as well as health [22]. Statistically, the man's hand can be about 18 mm longer, 50C. In fact, the difference may even amount to 45 mm, the man's hand is wider by about 9 mm, 50C and may actually be even wider by 24 mm than the woman's hand [22]. The dimensions of a hand are changing because of the aging process and the nature of physical work performed. Differences may also occur between the right and left hand, which is caused by the fact which human side plays a dominant role, whether the person is right-handed or left-handed. When designing tools for the European market, it is assumed that a handle for a hand tool should be 100 mm [22]. By analysing the data contained in Tables 2÷3 involving healthy population [21], it can be assumed that the length of a handle providing adequate comfort and coverage by a hand in clamping grip of a hand cannot be less than 96 mm and the gap between an object and a handle attached in two points is set in the range of 30÷50 mm. The diameter of a handle of a hand tool is also directly related

to specific dimensions of a hand. The recommended diameter of a handle of a hand tool based on statistics [4] (centile 50 and 90) should be in the range of 40÷50 mm for forcible work and for precise work the diameter should be 10 mm. For handles of tools for forcible tasks, the span between the two handles should not be larger than 90 mm for forcible work and 70 mm for precise work (centiles 50 and 90).



Fig. 2. Adjustable pliers with a ratchet
Source: [16].

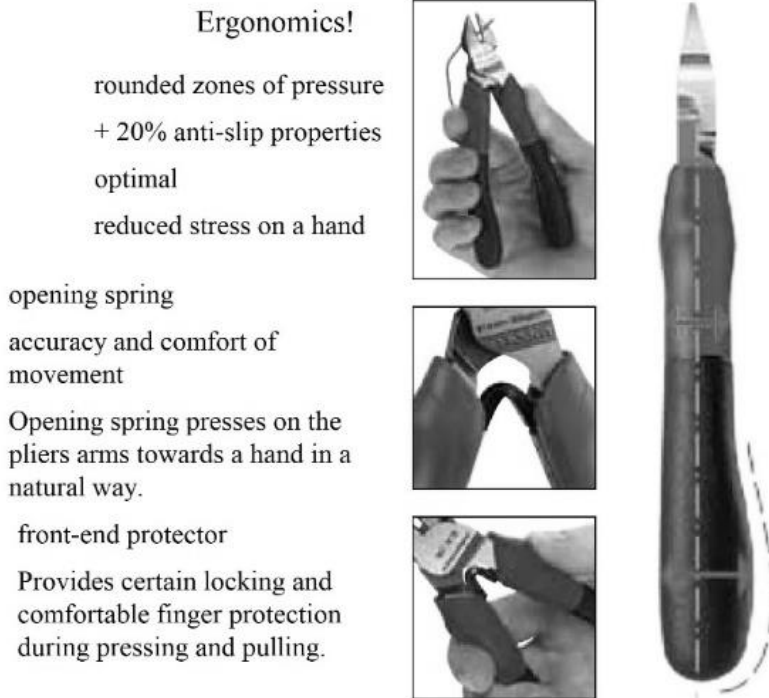


Fig. 3. Polished, lacquered pliers
Source: [16].

Designing hand tools in relation to shape and material of a handle of hand tools

During work, the operator's hand changes its position by moving on the handle surface of a tool. This is due to a number of factors, such as an employee's orientation reflex mechanism, gravity and pressure on a handle, work variability and repeatability of activities. The shape of a handle should correspond to the mechanical structure of the human body, taking into account not only the dimensions of individual parts of the human body but also the pressure on a handle of a tool. The handle of a tool should be adjusted so as not to cause inconvenience related to pressure on the inner part of a hand during work. Professional tools often lack cylindrical handles, and such a handle tends to rotate in a hand during work and pulls the epidermis. The shape of handles of hand tools should protect an operator against possible injuries and contribute to improving quality and productivity of work.

When choosing hand tools, attention should be paid not only to functionality, as previously mentioned, but also comfort and safety of use has an impact on the shape of a handle, low curvature and a wide cushioned handle that prevents the tool from sticking into a hand (Fig. 4).



Fig. 4. Ergo series pliers
Source: [13].

The appropriate span of a handle prevents clenching the fist as well as straining the last phalanges of the fingers. Correct rounding of a shield prevents a hand from slipping of the handle. Comfortable two-piece handles provide a secure grip, increased leverage effect and possibility of cutting thanks to optimum joint position, automatic unclenching of a handle using a spring mechanism ensures high comfort and safety of work. The shape of a properly shaped handle may significantly improve functionality of the tool. An appropriately modified handle can provide protection for critical areas of a hand.

The handle (Fig. 5) has been designed to be more stable and have better grip. Sharp edges that could cause discomfort during long work were eliminated. The narrowing of the front part of the handle facilitates precise handling with the tool. Thanks to special places for fingers, covered with anti-slip material, the grip of a tool was improved. The suitably shaped handle increased the contact surface of a hand with the tool which increased comfort of work and minimized negative flexion of a wrist.

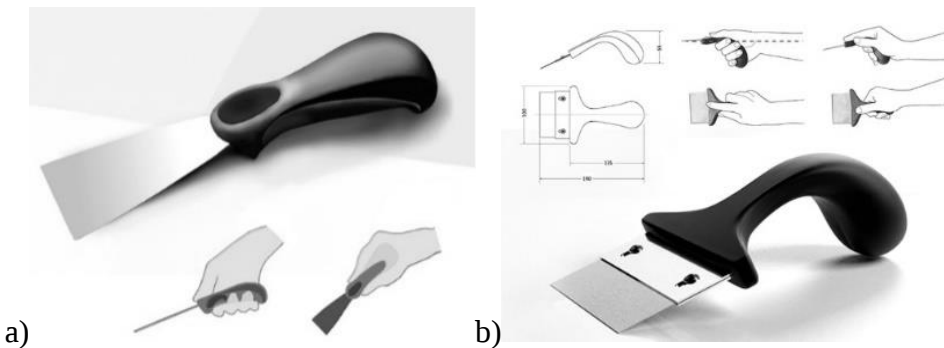


Fig. 5. A handle of a precise a) palette knife and b) a scraper
Source: [8, 6].

Properly designed handles of tools allow comfortable, long-lasting work within direction and distribution of forces specific to a given tool (Fig. 6). The working part is made of metal, the handle part is made of plastic. Sharper edges on the handles create a consistent form of the whole set. Small recesses spread in the areas of the largest contact surface of a hand and the tool provide better ventilation of a grip.



Fig. 6. Hand tools for ground works in nurseries

Source: [9]

The handle of a trowel has been designed to increase gripping properties of the tool. Properly shaped hilt enables easy rotation in a hand (Fig. 7). The right polymer material used at the end of the handle improves cushioning of vibrations that occur during work. An anti-slip ring was added at the base of the handle.



Fig. 7. A handle of a trowel

Source: [7].

The main assumption of the authors of the project was to integrate the shape of a hand with the handle in such a way as to increase the contact surface of a hand and to allow the change of grip during work (Fig. 8).

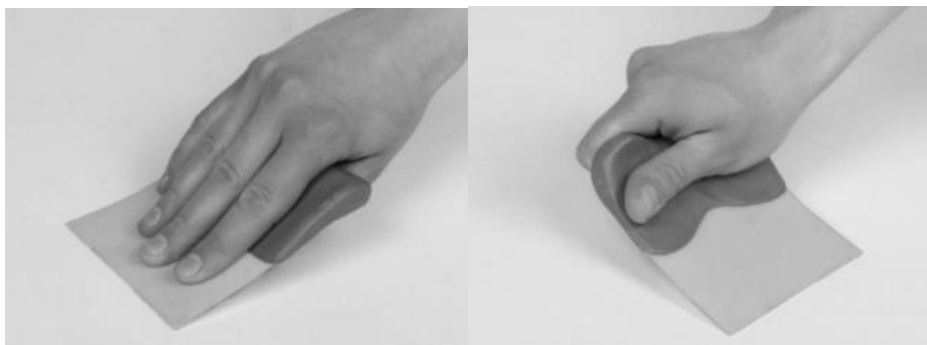


Fig. 8. A palette knife
Source: [10].

A properly designed handle of a finishing trowel allows for comfortable grip and easy change of a position (upper or lower grip) (Fig. 9). Thanks to appropriate profiles, an employee using a lower grip can operate near the work surface, which improves the stability of the finishing trowel.



Fig. 9. A handle of a finishing trowel (plastering trowel)
Source: [5].

Equally important in designing hand tools is to take into account the material from which the parts of a handle of the tool have been made. Lots of types of PVC polymers, ABS and SIR silicone rubber, which are resistant to extreme temperature changes, are used in production of handles (Fig. 10). A well-

designed shape of a handle may be insufficient when the material of a handle has not been properly selected. Appropriate material should protect an employee against slipping the tool from his or her hand, under varying working conditions, and depending on the purpose of the tool, it should also protect an employee from electric shock, burns and suppress vibrations.



Fig. 10. Insulated pliers
Source: [13].

At present, the tools with handles that are not secured with any material that improves e.g. grip can be found on the market. Using this type of tools can cause injuries while working; however, there are tools where handles cannot be finished with rubber or polymer material. Morse's pliers are often used in automotive industry - garage, workshop, factory for holding during welding, heating, for hydraulic work, also for cutting welding electrodes (Fig. 11). The lack of a shield is necessary because the external part of a handle might be damaged during work. Close attention should be paid and special care taken when using this type of tools.



Fig. 11. Morse's pliers
Source: [13].

Designing hand tools taking into account the degree of adaptation of the handle of a tool to an operator's hand

In everyday life ergonomics is not used in a large degree and an average worker associates ergonomics with comfort. The comfort of using multiple tools relates to right-handed people being the majority in the population. In case of left-handed people, the use of ordinary even best designed tools is impeded. Ergonomics applies to all utility items, not just tools. The simplest example in these days is a computer mouse, scissors, telephones, as well as furniture in the workplace such as chairs, tables with adjustable height of the countertop. In the context of left- and right-handed people, ergonomics is extremely useful for doing simple tasks. Ergonomic profiling of a handle allows a user to conveniently hold a pen or an ordinary tool, which helps to work faster, easier and longer.

A degree of adaptation of a handle of a hand tool in case of right- and left-handed people affects confidence in handling and comfort of work. This degree is expressed as the ratio of the area of a hand touching a handle during its use and the total area of a hand in a flat position [22]. A higher degree of adaptation limits the freedom of movement where greater freedom of movement with dynamic handles is required in order to find a compromise between the freedom of movement and the possibility of transferring greater forces.

The use of ordinary scissors for right-handed people by left-handed people becomes difficult. At present, the products for left-handed people are available on the market. Examples of such solutions are left-handed scissors (Fig. 12).



Fig. 12. Left-handed scissors
Source: [19].

Raising awareness with regard to the convenience of using hand tools means that there are various types of tools available on the market exclusively for left-handed people. In most cases, the awareness of what obstacles must be faced by left-handed people is low. For example, most rules are recommended for right-handed people. A left-handed person draws lines from right to left and the pitch on the tool is reversed (Fig. 13).



Fig. 13. Ordinary measurement tape for right-handed people
Source: [13].

A simple modification by reversing the scale immediately improves the comfort of using the tool (Fig. 14).

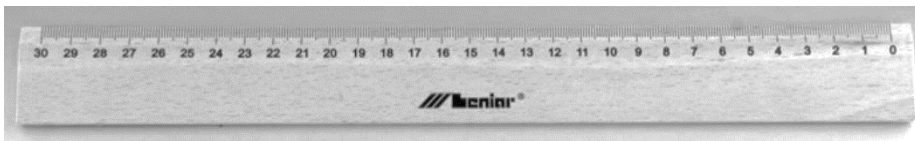


Fig. 14. A ruler for left-handed people
Source: [17].

In many cases, adapting tools for left-handed people causes that this type of a tool becomes less useful or difficult to be handled for right-handed people (Fig. 15-16).



Fig. 15. Micrometre for external measurements 25-50 for left-handed people
Source: [14].

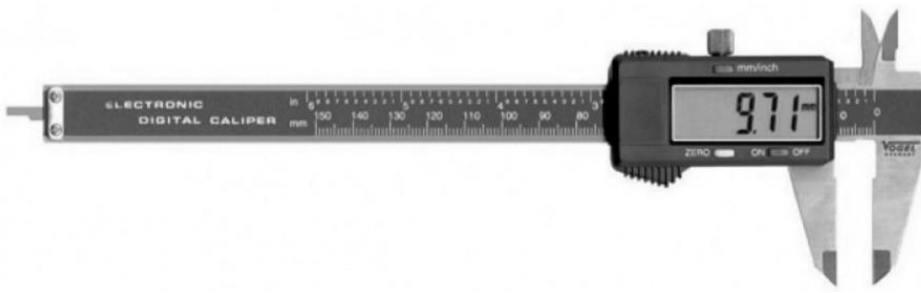


Fig. 16. Digital calliper for left-handed people
Source: [18].

Figure 17 shows tools designed for right- and left-handed people. The tools have been designed to fit well-defined handles and symmetrical shapes of the handles allow for work performed by right- and left-handed people. Finishing of the handles made it possible to eliminate gripping the tool in a place of a working part.

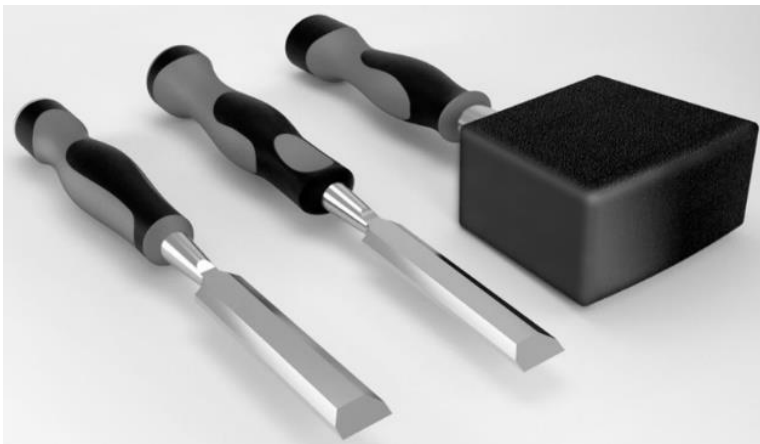


Fig. 17. Carpentry tools with universal handles
Source: [11].

Overview

By analysing the available literature of the subject, it can be stated that well-designed handles of hand tools improve safety and comfort of an operator's work. When designing hand tools, especially in case of handles, it is necessary to cooperate with lots of research and design centres in the field of industrial design. At present, the ergonomics of hand tools is becoming increasingly important in the markets and increases occupational safety. From the point of view of functionality of hand tools, an important element is adapting handles to individual needs of an operator, considering right- and left-handed people.

References

- [1] **Butlewski, M., Tytyk, E.:** The ergonomic features of non-powered hand tools used by technical service tasks, [in:] *Ergonomics in Contemporary Enterprise*. Ed. by Leszek M. Pacholski & Stefan Trzcieliński, Proceedings of the Eleventh International Conference on Human Aspects of Advanced Manufacturing, Agility and Hybrid Automation; and Fourth International Conference ERGON-AXIA, July 9-12, Poznań, Poland; IEA Press, ISBN 0-9796435-0-3, 2009.
- [2] **Butlewski, M., Tytyk, E.:** Wpływ ergonomicznej jakości niezmechanizowanych narzędzi ręcznych na efektywność pracy i zdrowie pracowników, [in:] *Modelowanie i inżynieria produkcji w ekorozwoju*, chapter 20, Politechnika Opolska, Opole 2008, 232-239.
- [3] Central Institute for Labour Protection – National Research Institute, <http://nop.ciop.pl/>, accessed on 16.09.2017.
- [4] **Gedliczka, A. et al.:** Atlas miar człowieka. Dane do projektowania i oceny ergonomicznej, publishing house: CIOP, Warszawa 2001.
- [5] http://wfp.asp.krakow.pl/ergonomia2/galeria.php?id_projektu=118 – accessed on 16.09.2017.
- [6] http://wfp.asp.krakow.pl/ergonomia2/galeria.php?id_projektu=119 – accessed on 16.09.2017.
- [7] http://wfp.asp.krakow.pl/ergonomia2/galeria.php?id_projektu=127 – accessed on 16.09.2017.
- [8] http://wfp.asp.krakow.pl/ergonomia2/galeria.php?id_projektu=128 – accessed on 16.09.2017.
- [9] http://wfp.asp.krakow.pl/ergonomia2/galeria.php?id_projektu=190 – accessed on 16.09.2017.
- [10] http://wfp.asp.krakow.pl/ergonomia2/galeria.php?id_projektu=209 – accessed on 16.09.2017.
- [11] http://wfp.asp.krakow.pl/ergonomia2/galeria.php?id_projektu=241, accessed on 16.09.2017.
- [12] <http://wfp.asp.krakow.pl/ergonomia2/pliki/Antropometria.pdf> – accessed on 16.09.2017.
- [13] <http://www.bahco.com/pl-pl/>, accessed on 16.09.2017.
- [14] <http://www.elektro-met.pl/pl/p/Mikrometr-dla-leworecznych-do-pomiarow-zewnetrznych-25-50-DIN863-01018031-MIB-Germany/4869> – accessed on 16.09.2017.
- [15] <https://www.i-feel-wiha.com/pl/>, accessed on 16.09.2017.
- [16] http://www.kron.com.pl/storage/offer/8_szczypce_r9w7n.pdf – accessed on 16.09.2017.
- [17] <https://www.leworeczni.pl/pl/p/linijka-drewniana-30-cm-leniar/200> – accessed on 16.09.2017.
- [18] <http://www.merazet.pl/produkt>, accessed on 16.09.2017.
- [19] <http://www.paznokcie-hybrydowe.pl/nozyczki-dla-leworecznych-model-jp10-left-rozne-rozmiary-p-2191.html> – accessed on 16.09.2017.
- [20] http://www.renex.com.pl/download/artykuly/reczne_11.pdf – accessed on 16.09.2017.
- [21] **Nowak, E.:** Atlas z roku 2000 zawiera prognozy na rok 2010 (Nowak E., Atlas antropometryczny populacji polskiej – dane do projektowania, Wydawnictwo Instytutu Wzornictwa Przemysłowego, Warszawa 2000.

- [22] **Polak-Sopińska, A.:** Konsekwencje niedostosowania uchwytów narzędzi ręcznych do ręki użytkownika, *Ergonomia niepełnosprawnym w wieku nanotechnologii i w ochronie zdrowia*. Pod red. Jerzego Lewandowskiego, Joanny Lecewicz-Bartoszewskiej, Monografie Łódź 2006.

**DESIGNING ACCESSIBLE
SOCIO-TECHNICAL ENVIRONMENT**

EVALUATION OF THE HOSPITALISATION CONDITIONS IN HOSPITAL WARDS IN LODZ FROM THE PATIENT'S PERSPECTIVE

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Abstract: Ergonomics is an omnipresent and interdisciplinary field of science. It influences the entire environment and, by caring about their comfort and safety and most of all, health, puts humans in the first place. The goal of the research was to evaluate the conditions of hospitalisation in hospital wards from the patient's perspective. 40 patients participated in the research – men and women from Z. Radliński Regional Orthopedic and Motor Organ Rehabilitation Centre and Cardilogic Rehabilitation and Internal Medicine Clinic in Lodz, aged 45-80. The research utilised an original questionnaire prepared for this research. Among all of the patients, 31 were satisfied with their stay at the hospital. 9 patients were not satisfied and 5 listed inappropriate fittings in the toilets and bathrooms as one of the reasons. The patients in hospital rooms were particularly satisfied with their hospital beds and room lighting. The biggest concerns were overcrowding of the rooms, insufficient ventilation as well as low number of toilets and bathrooms.

Keywords: ergonomics, functional conditions, health, safety.

Introduction

Ergonomics is a field of science which nowadays applies not only to workspace, but also provides a broader perspective of humans and their functioning in different environments. It is important for the technical object (including buildings) to answer the people's expectations. High technological level with ergonomic criteria taken into account, helps shape the space of public utility buildings so that they are adjusted to all people's needs [13]. Additionally, the ergonomic progress in equipment and fittings production, is supposed to provide the safety of use to anyone, along with aesthetic qualities [14].

Universal design which takes into account the needs of all users including physically challenged people, patients and seniors, should be followed unconditionally in architectural development, and implemented in the process of thinking about ergonomic shaping of the environment which surrounds every human. Each user should have the possibility to appropriately and fully use the

environment as soon as in the initial phase of design, without the need to modernise and redo the already existent spaces [6].

The growing number of so called “long-lived” people affects the growth of elderly people population including physically challenged people. This creates new possibilities as well as challenges in ergonomic design and geriatric care [8, 10].

The evaluation built on patient’s experience is incredibly important in the process of improving the quality of patient’s functioning in the healthcare facility. Appropriate hospitalisation conditions provide not only less inconvenient work conditions for medical personnel, but most of all, help patients feel better. Organisation of appropriate hospitalisation conditions suitable for people, is not only a condition which needs to be met, but also an important factor influencing the speed of recovery [1, 4, 3].

Research goal

The main goal of the research was to evaluate the hospitalisation conditions in the hospital wards, from the patient’s perspective. The factors causing inconvenience were analysed in terms of ergonomic quality and selected patients’ satisfaction aspects. The obtained results will be a foundation for further research, which will provide answers to what was the reason for possible inconveniences, as well as actions aimed at the improvement of current state of things.

Materials and methods

40 patients from Radliński Regional Othopedia and Motor Organ Rehabilitation Centre and Cardiologic Rehabilitation and Internal Medicine Clinic in Lodz participated in the research – 25 women and 15 men aged 45-80 ($61,15 \pm 4,22$).

The screening criteria were: age ≥ 45 yo., length of hospital stay (more than a week at the time of the research), medical diagnosis or identification proving problems with the motor organ, patient’s consent. The eliminating criteria were: age below 45 yo., lack of patient’s consent; hospital stay shorter than a week at the time of the research.

Patients were informed about the goals of the research, lack of risk from the participation in the research as well as the possibility to withdraw at any time, with no consequences.

The research utilised an original questionnaire prepared for this research. The questionnaire was divided into two parts: first part focused on the demographic data while part two featured 19 questions focused on the adjustment of hospital rooms to the patients’ needs (equipment, number of people in one room, lighting, comfort related to heating and ventilation in the room); ergonomic quality of the mattress

and hospital bed (comfort of the bed and possibility to perform exercises on it); technical condition of toilets and showers as well as adjustment to the needs of people with motor organ dysfunctions and patient's general satisfaction with their stay at the hospital.

Institutional Review Board's approval for the research was granted.

Results

Table 1 features a detailed characteristic of the examined group. The participants were asked to evaluate their hospital room in terms of living conditions on the following scale: very good, good, normal, bad, very bad. "Normal" was the most popular answer, given by as many as 12 respondents. 9 rated their room "bad" including 4 "very bad" answers. Only 2 respondents gave the first answer.

Table 1. Characteristics of the sample group in terms of age and gender

Age	45-55		56-65		66-80		> 80		SUM	
Sex	N	%	N	%	N	%	N	%	N	%
Women	3	12%	7	28%	8	32%	7	28%	25	100%
Men	2	13%	5	33%	3	20%	5	33%	15	100%
SUM	5	12.5%	12	30%	11	27.5%	12	30%	40	100%

Source: own elaboration.

After analysing the number of people in one hospital room, it turned out that unfortunately all respondents stayed in overcrowded rooms with 6-8 or more people in each of them.

22 respondents were satisfied with the heating and ventilation of their room. The rest was not satisfied with their room. After the analysis of the reasons for such dissatisfaction, we found that the main reason for the state of things was the overcrowding of the room (declared by 8 patients) and insufficient airing of the room (declared by 7 patients).

The analysis of the ergonomics of the windows located in hospital rooms proved that they provide enough sunlight (13 respondents) and that the adjustment of how much the window is open is easy (12 respondents). 9 respondents considered the windows easy to open and 2 respondents considered the windows too airtight.

4 patients considered the lighting of the hospital room very good, 18 gave the "good" answer, 17 thought it was normal. Only one respondent gave the "bad" answer. There were no answers suggesting that the lighting of the hospital rooms is very bad.

Considering the state of the fittings of the hospital rooms, the majority of respondents declared that it is on a good level with as many as 19 choosing the "normal" answer and 11 considering the fittings good. Unfortunately 8 respondents

thought that the state of the hospital room fittings was unsatisfying. The findings were presented in Figure 1.

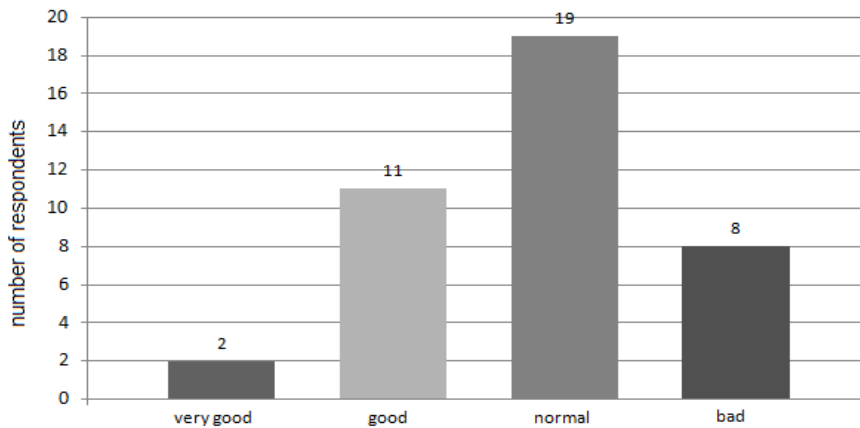


Fig. 1. Analysis of the equipment of the hospital room
Source: own elaboration.

Hospital beds and mattresses were also examined in terms of ergonomics. 29 respondents were satisfied with their mattresses comfort and called it comfortable. 11 people deemed them uncomfortable, mainly because of their hardness (16 respondents) and presence of irregularities which they called subsidencies (8 respondents). 3 people listed excessive softness of the mattress as the main problem.

As for the possibility to perform exercises in the hospital bed, 26 considered the bed comfortable, while the remaining 14 patients did not think their beds serve this purpose.

As proved in the research, the most often declared characteristics which affect the unsatisfying level of ergonomics of the bed were: too difficult adjustment of the headrest (5 respondents), neighbouring beds located too close (4 people) and the lack of bed height adjustment possibilities (3 patients). The acquired data can be seen in Figure 2.

Evaluation of safe movement in the hospital corridor. 15 respondents considered the safety good, 4 chose the “very good” answer. Only one respondent considered the movement very difficult and sometimes almost impossible. The research proves that the reasons for difficult movement around the corridor were the following: lack of railings and handles on the walls (14 respondents), too narrow corridor (10 people), obstacles on the way i.e. garbage bins, chairs, tables, rehabilitation equipment (9 respondents) and slippery floor (3 patients).

Very good feedback was obtained in the question regarding the numbering and signage of the hospital rooms. Not one “bad signage” or “very bad signage” answer was recorded. 8 respondents gave the “very good signage” answer while 14 considered it normal. The majority (18) considered the signage good.



Fig. 2. Evaluation of the ergonomics of the hospital bed

Source: own elaboration.

The hygienic and sanitary rooms were also evaluated in terms of accessibility. Among the obtained answers, the majority was negative. Almost half of the respondents (18 people) considers the accessibility of these rooms bad. The results in regard to the accessibility to hygienic and sanitary rooms were presented in the Table 2. The problems related to the use of hospital toilet included: small space (18 patients), lack of division into men's and women's rooms (9 people). The answers also included the following: toilet situated too low (4 respondents), lack of railings and handles (3 respondents) and doors opening to the inside (3 patients).

Table 2. Analysis of the accessibility of the hygienic and sanitary rooms based on patients' age

Access to the hygienic and sanitary rooms		Age				SUM
		45-55	56-65	66-75	76-80	
very good	N	-	1	-	2	3
	%	-	8.3%	-	18.1%	7.5%
good	N	-	-	3	1	4
	%	-	0.0%	25.0%	9.1%	10.0%
normal	N	-	3	2	3	8
	%	-	25.0%	16.7%	27.3%	20.0%
bad	N	3	6	5	4	18
	%	60.0%	50.0%	41.6%	36.4%	45.0%
very bad	N	2	2	2	1	7
	%	40.0%	16.7%	16.7%	9.1%	17.5%
SUM	N	5	12	12	11	40
	%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: own elaboration.

31 respondents were satisfied with their stay at the hospital (Fig. 3).

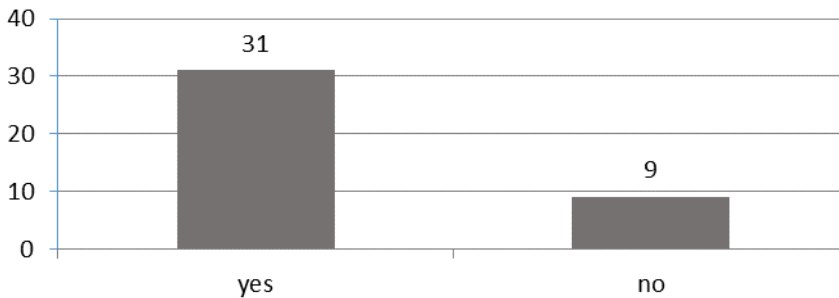


Fig. 3. Analysis of the results of patients' individual evaluation of the satisfaction with the hospital stay

Source: own elaboration.

The remaining respondents listed the following reasons for the lack of satisfaction with their stay: too few toilets and bathrooms (4 respondents), too many people in the room (3 respondents) as well as insufficient ventilation and fittings in the rooms (2 respondents).

Conclusion

High level technology which incorporates the principles of ergonomics allows such shaping of spaces in the public utility buildings, that they are adjusted to all people, with emphasis on elderly and physically challenged people. The rating which is derived from the patient's experience is particularly valuable in the process of improving the quality of healthcare facilities. Available literature [2, 3] proves that the number of "long-lived" people is growing which will contribute to the increase of the physically challenged people in the elderly population. This creates new challenges in the ergonomic design of buildings and geriatric care.

In his expertise on the medical mistake conditioned on the ergonomic factors, Pokorski [9] stresses that the beginning of the 21st century is the time of increased interest in the problem of patient's safety.

The report by Institute of Medicine (IOM) [12] lists the important tasks of the healthcare system in terms of interdisciplinary and complex approach to the improvement of the patients' healthcare, their safety, increase of the satisfaction with their hospital stay and reduction of the stay costs. The abovementioned report also states that in order to increase the safety of patients, the number of collective rooms should be reduced in favour of single or double rooms. The conducted research proves that the hospital rooms are overcrowded since often there were up to 10 people in one hospital room.

As proved in a research by Lord et al. [7], hospitals are a place where accidents happen frequently, which prolongs the hospital stay and contributes to the drainage of the healthcare system financial assets.

In authors' research, despite overcrowding, patients had positive opinions about the hospital rooms in terms of spaciousness and fittings (which affect the accident risk).

According to Wróblewska [16], every person has congenital abilities which help them examine the microclimatic conditions. Thermal well-being is the representation of satisfaction with the thermal environment present in the room. If these conditions are considered comfortable by more than 80% of the people, they can be considered acceptable.

Original research proves that only a little bit more than a half of the respondents considered the room acceptable in terms of proper ventilation and temperature. This may be the reason of significant overcrowding of the rooms.

Respondents were mostly unsatisfied with the accessibility and standards of the hospital toilets. According to the directive of the Minister of Infrastructure [11] regarding the technical conditions the buildings should meet and their location in public utility buildings, on floors accessible by physically challenged people, at least one of the hygienic and sanitary rooms should be accessible by this group of people.

The research also focused on the analysis of the lighting conditions in the rooms. As proved by Ulrich et al. [15], proper amount of daylight and artificial light in hospital rooms affects the general well-being and has direct effect on the improvement of the hospitalisation results in patients suffering from depression.

Authors' research proves that the majority of the patients considered the lighting conditions in the hospital appropriate and satisfying.

As proved in the research conducted by Krekora et al. [5] focused on the influence of the hospitalisation on the quality of life of patients who underwent a stroke, in order to provide mental comfort, good life quality needs to be maintained, meaning that expectations need to be met to a certain extent. It is important for patients and the medical personnel alike. These expectations are as follows: temperature, humidity, air circulation, lighting and hospital beds as well.

In the respondents' opinion, the hospital rooms are adjusted to the patients' needs when it comes to utilitarian conditions, especially in terms of fittings, spaciousness and possibility to maintain cleanliness in the room. The lighting of the rooms and the hospital beds received the highest ratings while overcrowding, insufficient ventilation of the rooms and too few toilets and bathrooms were the biggest problems. Despite the drawbacks, most of the patients were satisfied with their hospital stay.

*

The research identified the areas in need of intervention and significant improvement. The obtained results will be a prelude to further research which will identify the causes of these inconveniences and problems. These in turn will be a basis for specific actions aimed at the improvement of the current state of things.

References

- [1] **Chmielewski, D.:** Servqual – metoda badania jakości świadczonych usług zdrowotnych. *Przewodnik menadżera zdrowia*, 6 (13), 2016, 17.
- [2] **Henriksen, K.:** Opportunities and Challenges in the Pursuit of Patient Safety, [in:] *Handbook of Human Factors and Ergonomics in Health Care and Patient Safety*, Taylor and Francis Group, New York 2010, 20.
- [3] **Kabsch, A.:** Potrzeby rehabilitacji w przewidywanej przyszłości, [in:] *Ergonomia niepełnosprawnym w przyszłości*, J. Lewandowskiego, J. Lecewicz-Bartoszewskiej, M. Sekrety (eds.), Wydawnictwo Politechniki Łódzkiej, Monografia, Łódź 2003, 240-249.
- [4] **Kowal, E.:** Projektowanie ergonomiczne dla osób niepełnosprawnych, [in:] *Ekonomiczno-społeczne aspekty ergonomii*, Państwowe Wydawnictwo Naukowe, Warszawa-Poznań 2002.
- [5] **Krekora, K., Bittner-Dzapińska, E., Lecewicz-Bartoszewska, J. et al.:** Znaczenie warunków hospitalizacji dla jakości życia chorych po udarze mózgu, [in:] *Ergonomia niepełnosprawnym w przyszłości*, J. Lewandowskiego, J. Lecewicz-Bartoszewskiej, M. Sekrety (eds.), Wydawnictwo Politechniki Łódzkiej, Monografia, Łódź 2003, 251-255.
- [6] **Kuryłowicz, E.:** Projektowanie Uniwersalne. Udostępnianie otoczenia osobom niepełnosprawnym. Centrum Badawczo-Rozwojowe Rehabilitacji Osób Niepełnosprawnych. Warszawa 1996.
- [7] **Lord, S., Sherrington, C., Menz, H.:** Falls in older people. Risk factors and strategies for prevention, Cambridge 2007, 311.
- [8] **Olszewski, J.:** Podstawy ergonomii i fizjologii pracy. Akademia Ekonomiczna w Poznaniu, Poznań 1997.
- [9] **Pokorski, J.:** Ergonomiczne uwarunkowania błędów medycznych, Ekspertyza przygotowana w ramach działalności Komitetu Ergonomii przy Prezydium Polskiej Akademii Nauk, Kraków 2008.
- [10] **Rosner, J.:** Rachunek ekonomiczny w ergonomii, [in:] *Ergonomia*. Państwowe Wydawnictwo Ekonomiczne, Warszawa 1985.
- [11] Regulation of The Minister of Infrastructure of 12 April 2002 on Technical Conditions, which Should Correspond to the Buildings and Their Location (Dz.U. Nr 75, poz. 690).
- [12] *Transforming Hospitals: Designing for Safety and Quality*. Agency for Healthcare Research and Quality. Advancing Excellence in Health Care, www.ahrq.gov
- [13] **Tytyk, E.:** Definicja, przedmiot i zakres ergonomii, [in:] *Nauka o pracy – bezpieczeństwo, higiena, ergonomia*. Ergonomia – pojęcia podstawowe, D. Koradeckiej (ed.). Pakiet Edukacyjny dla Uczelni Wyższych, Warszawa 2000.
- [14] **Tytyk, E.:** Geneza ergonomii jako dyscypliny naukowej, [in:] *Projektowanie ergonomiczne*, Państwowe Wydawnictwo Naukowe, Warszawa-Poznań 2001.
- [15] **Ulrich, R., Zimring, C.:** The Role of the Physical Environment in the Hospital of the 21st Century: A Once-in-a-Lifetime Opportunity, Robert Wood Johnson Foundation, 2004, 20-21.
- [16] **Wróblewska, M.:** Ergonomia skrypt dla studentów, Opole 2004, 50-61.

CONTEMPORARY TRENDS IN THE DESIGN OF HOSPITAL WARDS IN THE CONTEXT OF ERGONOMIC ISSUES

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Abstract: The article presents issues related to the design and modernization of hospital bed units in the context of ergonomic issues. Currently in Poland, most of the health care facilities are being modernized. However, the technical and law regulations specify only minimum requirements and leave a lot of room for interpretation. Designers are usually faced with the task of bringing together the needs of users and investors on a limited budget, and the need to choose functional and aesthetic solutions. The use of Evidence-Based Design (EBD) method, allows to reach optimal solutions, which take into account the needs of both the patient and the personnel.

Keywords: healthcare, hospital wards, bed wards, evidence based design for hospital facilities, ergonomics in healthcare.

Introduction

Among the many sections of modern hospital's daily operation, bed wards are taking up most of the space and are a place where patients spend the most time while recovering. Modern hospital bed wards are a fairly new architectural concept, since it has its source in XIX century process of secularisation of the hospital institution. Which instead of being primarily a charity started to play a role of health care provider. Present-day hospital managers are faced with tough competition in winning the patient over. The hospital building itself can become a valuable asset in the shaping of healthcare facility's business image.

Technological advances in health care are fast, requiring the law regulations to change and adapt for particular spaces. It is eminently present in the modern diagnostics and surgery wards. Hospital bed wards, as spaces primarily utilised for recovery, rehabilitation, therapy and observation of patients, are among the largest of hospital's areas of functionality and are a place of work for a diverse staff of hospital employees. Work ergonomics in a bed ward are critical for nurses and physicians as well as for technical, cleaning and administration employees. Following the broader definition of ergonomics which aims at "providing organisation and material framework for a human being to achieve physical and material state of well being, seeking optimal solutions for a wide

range of human activities” [29], ward’s space arrangement has far reaching consequences exceeding measurable benefits. Modern hospital facilities should meet present day cultural, environmental and esthetic requirements.

The ergonomy of technical elements (buildings, furniture, hospital equipment) has a social and economic value [3]. Subpar quality has both measurable economic and immeasurable moral consequences (including physical suffering, mental strain, low work ethic, lack of subjectiveness, growing passiveness and pathy). On the other hand the architectural quality of a healthcare facility, also impacts the way the facility is perceived by the local community, increasing its’ attractiveness.

After World War II healthcare facilities have become a priority for the government in Poland. In order to accelerate the investing process, government agencies developed standard projects for this kind of buildings, which, similarly to the housing market, led to the cost reduction and “rationalisation” of hospital building. Most of the facilities of that era were erected in 1960s and 70s. By 1970s the market saturation with county hospitals (basic health care level) reached its peak.; other levels of the system included specialised centers (national and university) and the government department healthcare (mining, army and rail).

After the political system transformation, healthcare infrastructure of the 1990s was still being invested in and new healthcare facilities were built. Recent years, following the EU access, are a time of rapid investment growth in this branch of construction due to many opportunities for obtaining funds. Currently there are over 1000 hospitals in Poland. The majority is after, in the midst or expecting modernisation in order to meet the current requirements and needs. It is an opportunity to utilise optimal design solutions, based on scientific approach (Evidence-Based Design), which in turn will increase the quality of service available to patients by giving the advantage in the competitive healthcare market.

The current state of research

Qualitative research in architecture and urban planning is one of the currents of interest common to architects, psychologists, sociologists and other professions concerned with the advance of social and psychological sciences in the field of behavioral theory. In the 1960s and 70s several theoretical papers were published on the quality of urban environment, public spaces, dwelling areas and general surrounding and its implications on the wellbeing and behaviour of people [1, 9, 12]. Post-Occupation Evaluation (POE), developed in the 1980s, is a new serious architectural object quality evaluation tool, which allowed the perfecting of a design process through ex-post study. The study’s quality criteria included: functionality, technical details, behavioral patterns as well as organisational and economic criteria. In the following decades POE method was enhanced with a new concept of building’s quality analysis

through its' entire lifecycle: planning, programming, designing, construction, modernisation and finally demolition [19]. Preiser coined a name for this new approach – BPE (Building Performance Evaluation). A twenty year old paper by A. and E. Niezabitowscy states that “This method is practically unknown in Poland. It causes controversy and suspicion in the professional design community. Many architects are frightened by the vision of the end user evaluation, not taking into account it's important impact on the design skill development” [18]. Unfortunately one has to admit not much has changed through the time.

Evidence-Based Design (EBD) is architectural design approach based on scientific proof. Performance and impact comparison studies performed in a particular design solution, against proven case studies, allow to make an optimal choice. This method's help is appreciated in many areas of architectural design. The model based on scientific evidence may be used in most design decision making processes, especially in projects of complex functionality. What is interesting, this approach may stand in contrast to the tradition of treating every project individually, uniquely as an architectural challenge solved only by the architect's talent, which can overcome the lack of experience in a particular type of project.

Since 1972 architectural space solution of a healthcare facility, was examined from the point of view of patients' benefit. In 1970s healthcare buildings were under critique for their quick aging in contrast to “the acceleration in programming and design of new hospitals.” To face the unpredictable evolution of science and technology a break from traditional concept of architectural object as definitely resolved and finished was needed [25].

USA have been a leader in the field of EBD (Evidence-Based Design) in recent decades [8]. The Center for Health Design (CHD) is propagating the use of EBD method in healthcare facility design. The Center defines the method as an “intentional try to base all structural decisions on best available research evidence, aiming at improving the outcome and monitoring further success or failure”. Method's efficacy in designing of healthcare facilities is broadly covered in Jain Malkin's paper, [15] pointing to the fact that far less studies have been made to determine the relation of the buildings' quality with the quality of work performed by the employees and their wellbeing [34].

Further studies have found that certain architectural solutions may promote and some may limit the occurrence of medical error. J. Piskorski [21] formulates a medical error as “a prerequisite for the undesired occurrence in a healthcare system” conditioned by ergonomic factors. He finds the most important risk factors to be material environment conditions and systems design including organisational culture, hidden errors, information circulation and ergonomics problems. Among the ergonomics issues several architectural solutions are listed, which can lead to adverse events.

In the 1990s Ulrich proposed his Theory of Supportive Design [26] stating that an optimal space arrangement of the patient's surroundings leads to lowered

environmental stress in patients experiencing loss of control over their immediate surroundings. Lowered levels of stress are beneficial to the process of patient's recovery. According to Ulrich there are three main guidelines when designing health care buildings:

- architectural and technology solutions allowing the patient to control their immediate physical and social environment (the ability to regulate the physical environment's parameters and conditions for social interaction),
- social support availability,
- an introduction of positive elements in the surroundings, distracting from the patient's state of health.

Comprehensive English-language literature research up to 2015, shows a large number of publications supporting the thesis that there is an association between the psychological and physical well-being during the process of recovery with the quality of the healthcare facilities' interior [11].

Spatial arrangement's role in the organization of bed units

The way the space of a bed ward is arranged and the architectural interior design depend to a great extent on the work organisation system to be implemented in the facility and the management of individual areas of healthcare building.

The most common model for bed wards in healthcare facility development, is based on the kind of medical condition. Bed ward intended for the treatment of patients having certain medical conditions are a basic organisational unit of stationary treatment in traditional healthcare. Additionally patients are split according to their sex. Wards are typically subdivided into individual nursing areas.

Another approach to this problem is a concept of Progressive Patient Care (PCC) introduced in the USA in 1950s. This approach is characterised by sorting the patients according to the severity of their condition rather than just the type of it. PCC healthcare facilities do not have the traditional bed wards intended for individual types of medical conditions. In PCC hospital patients' admissions are based on the necessary help to be administered: intensive, intermediate and minimal care as well as self-care and convalescence. There have been instances of a mixed approach used in medical construction industry.

Modern approach to the design of the hospital bed ward focuses on the elasticity of used space solutions and the ability to make any future changes according to needs. What is interesting is the fact that this "futuristic" approach was propagated as early as 1970s. Quick technology and thus medicine advance of that era made people aware of the probability that the building may soon become outdated. Another aspect of this issue is the big financial cost of healthcare building modernisation. Authors of monograph on Designing healthcare facilities from 1973 point to possible solutions to the aging problem:

- Demolition of buildings unfit for modernisation.
- Designing of more temporary buildings, with intended life span of 20 years.
- Designing of buildings of form and construction easily rearranged and rebuilt in the face of changing needs [13].

This last approach is still valid today. The expected lifespan of a healthcare facility is counted in tens of years, meanwhile the lifespan of installation and technical equipment is expected to be over a dozen or so years. On the other hand the lifespan of medical equipment meeting present day standards is about 8 years long [23]. These differences are the main reason behind the fact the designing process of healthcare buildings and their modernization, need to be approached from a wider perspective. Unlike so far, the project is never finished and complete, and should be treated and planned as an adapting and changing system.

Employee work organization and comfort in the hospital bed unit, are basically organized around the individual nursing areas. According to architectural shaping several general types may be singled out:

- corridor arrangement,
- two corridor arrangement,
- central multilateral or round arrangement.

The majority of hospitals in Poland have wards designed along a basic corridor arrangement. Rooms are situated on one side of a corridor and personnel areas on the opposite side. Nurse post is situated more or less in the middle of the ward's length. In the immediate vicinity there should be a bathroom to care for immobilized patients, observation and single rooms as well as laundry. "Diagnostic and procedure areas should be located near the entrance to the ward, meanwhile right next to it a dayroom should be situated with the ward's kitchenette" [20].

The two corridor arrangement allows to shorten the overall length of the building thus making the communication routes shorter. Such arrangement requires an inclusion of inner courts to provide the necessary amount of light.

Central arrangements are the most ergonomic of the three in the aspect of short communication routes between the rooms and nurse stations. However they accordingly take up most space on the parcel which is typical for a building of scattered structure.

In order to achieve a better work organization there is a tendency in nursing teams to be divided into smaller units surrounding the nurse station. Such tendency may be enforced by decentralizing of spaces common to the ward. Such spaces include laundry and linen storage which can be distributed to several smaller storage compartments. Such arrangement is not without its faults, it encourages the staff to deposit and store unintended objects [5].

Number of beds in a hospital room

In the Polish legal system one can notice a decline in construction requirements for healthcare facilities, and on the other hand a rise in requirements for the technical infrastructure and equipment. Health Ministry issued a decree on June 22, 2005 regarding the requirements that should be met in professional and sanitary respects by rooms and devices of a healthcare facility [31]. It detailed the precise living area norms for each bed depending on the number of beds in room and the type of ward they were in. The number of beds in a room dedicated to stationary recovery was limited to five. A minimal distance between beds was determined (min. 70 cm) and between the beds and the outside wall – min. 80 cm. The bill also detailed the requirements for general construction in the regard to interior finish, communication, lightning etc.

Current regulations [31] describe the minimal requirements for hospital bed rooms, however the bill itself leaves plenty of room for interpretation. The minimal living areas and space between the beds are no longer strictly defined. The size of the room itself is described indirectly by a number of other regulations. The number of beds per room is limited only in particular wards. In the Neonatology Wards “mother and child” rooms may be occupied by no more than two mothers and two babies with the option of adding a third bed for the newborn.

Two person rooms are regarded as the best suited arrangement for most patients. Such rooms offer the necessary social interaction, which is especially important in the time of crisis [17]. Ideally it would be to leave a choice to the patient between a two and single person rooms [17]. Single and two person rooms are also more easily arranged to have a positive impact on the process of recovery and provide more work comfort to the personnel.

Today norms for nurse employment in public healthcare facilities are based on mathematical formulas which take into account a number of factors. These formulas’ outcome is a number of full time nursing position per a single hospital bed required to provide sufficient care to patient. These formulas are constantly negotiated by the nursing unions [32]. Zofia Małas – the chairwoman of nurses and midwives council, defines the optimal number of patients per a single nurse to be between 6 and 8 [36]. Finally, the current nurse employment formula’s outcome is not unequivocal. Being able to tell the number of employed people is crucial from the point of finding correct spatial solutions organizing the rooms, nurse stations and social areas. The maximum number of four patients in a room, guarantees optimal care delivery by a single person on regular check visit. Accordingly distributing the beds in a room can improve the patient’s feeling of intimacy, especially when using screens between the beds. Minimal distance between beds in such arrangement should be 105 cm. Arrangement of three neighbouring beds is significantly more uncomfortable for the patient and should not be considered. In the newly designed hospitals the majority of rooms is two-person, at the same time the number of beds per room rarely exceeds four in a modernised facility.

The modern design of healthcare facilities is characterized by its approach to a single room as a standard. According to British Department of Health guidelines, based on scientific research of patients preferences, at least half of new beds are to be in single-person rooms; same applies to modernized facilities [33]. Research shows that single patient rooms have several advantages. The most important are: more intimate and direct patient-personnel contact, less stress for the patient and even less risk of medical error [27]. It's disadvantages: the need to cover greater distances by personnel, the feeling of estrangement, limited patient-personnel eye contact.

Turnbridge Wells Hospital in Pambury, Kent is a good example of this approach in modern design. It's arranged only of single-patient rooms. The hospital won an award of the National Patient Safety Agency for providing the patients with more friendly rooms, reducing stress, limiting the risk of infection and supporting the presence of patient's family [35]. However, the survey conducted among the personnel showed that from their perspective the single-room arrangement has several faults [6]. The personnel was concerned predominantly with possibility of patient falling and the staff reaction taking a long time. In a multi-bed room other patients can help alarm a member of personnel. Another benefit of multi-bed rooms is a better interaction between the personnel and the patients. Patients were more sympathetic and the personnel work was more comprehensible to them. Patients in single-person rooms tended to feel neglected and lonely.

Bed wards spatial arrangement in the light of legal requirements

According to current Ministry of Health requirements, unified hospital bed wards should comprise of the following areas: patient room, nurse station with adjacent preparation room, diagnostic-surgery room and sanitary areas. The legislator allows group bathrooms, although single room bathrooms are a standard. Patient bathrooms should be fitted with washbowls, lavatories and a shower (it may include a specialised wheeled bath allowing to wash the bed-ridden patients). At least one bathroom should be adopted for wheelchairs. The specificity of certain hospital wards requires additional factors to be taken into account. Intensive Care unit, for example, should be well communicated with other units of the facility such as Emergency, Admissions and Surgery. The patient entering the Intensive Care Unit should be brought in through a lock. Same rule applies to the personnel of the Intensive ward.

General purpose areas include employee rooms (medical and administration), ward kitchen area, toilets for staff and visitors, cleaning cupboards, magazines. Regulations allow the shared use of such spaces between the wards but such solution is rarely applied.

Apart from legal obligations the need to compete with other health facilities has influenced the rising standards. Modernisations, usually limited to refurbishment, reconstruction or expansion

Bed ward organisation in the context of personnel's work comfort

Work in a hospital bed ward is particularly specific for it requires the performance of various activities. Their unpredictability is a serious stress factor influencing the quality of work performed.

Despite the growing popularity of social participation in planning, in the case of modernizing or creating workplaces, the decisions are made beyond the personnel [4]. It is partially caused by the need to keep the planning process quick while discussions and reaching compromises are a difficult and lengthy process. Presenting the concept to the personnel or future users and interested population is a good practice and an intermediate solution, it should be conducted in strict cooperation with the architect.

Nurses are a professional group particularly liable to overstrain due to burdens at work, such as patients, equipment, medical appliances and furniture. In a research survey covering 1500 nurses and midwives, 80% of partakers pointed to this type of activity as most inconvenient [14]. The same survey also shows that nurses employed in hospitals are burdened by long standing periods; 60% of responders stood for more than 3 hours per day; 30-40% is walking for more than 3 hours per day. One third of nurses have indicated the need to holding uncomfortable positions for more than an hour at a time (such as kneeling, squatting etc.). 74% of surveyed employees complained about insufficient space dedicated to performing their duties and lifting burdens [14]. Another research survey performed in Berlin on more than 1000 respondents. It showed over 80% dissatisfaction with too long walking distances, lack of space, bad room arrangement and lack of social space [4].

A question arises, whether modern tendencies in architectural design, can come and meet the needs of patients as well as hospital's personnel including nurses in the bed wards, to help improve healthcare conditions.

As far as ergonomy issues are concerned the most important recent legal requirements change regard: §18, §19 and §20 [31]. Previous regulations were very specific in regard to the width of the room allowing the beds to be individually moved without moving other beds. It has been recently changed to be far less specific and states only the ability to move the bed [31]. Another requirement for the minimal width of the ward's door have been removed.

One of the most important features in the modern bed unit is the ability to make eye contact with the patients to monitor their state of health. Most of the time the door to bed ward should be slightly ajar allowing discreet monitoring of patients.

During the doctor visit in the ward and nurses checks, the interaction between the patient and the personnel often happens in a tiresome form of an employee standing over the patient. This discomforting situation can be alleviated by providing the personnel with seats allowing the doctor or nurse to maintain eye level contact with the patient. Such solution, however, requires more space to be designed next to bed in the ward.

Patients comfort in regard to bed wards arrangement

The feeling of losing control over one's immediate everyday surroundings, the intrusion into one's intimacy, dependence on personnel's help, are only some of the main reasons behind low psychological condition accompanying work and stay at the hospital. According to supportive design theory [26] the ability to control one's surroundings is a factor in lowering of stress levels and thus benefiting the overall state of health for the patients. The research shows that an adjustable bed giving the patient individual control in addition to controlling other parameters of patients surroundings (light intensity, temperature, sound) act as an important factor in the lowering of the environmental stress [10].

The basic intimacy area for a patient in a multi-bed ward is limited to his or hers own bed, night stand and bed control panel (lightning, communication, and medical gas installation). Since the space for personal belongings is often described to be problematic and insufficient; it is put forward to include separate furniture elements in the design fulfilling the role of personal lockers.

Aesthetic issues

Modern single-bed solution used in the design of hospitals is influenced by the design trends in the hotel industry. It expresses the EBD premise that a healthcare facility should be hospitable and welcoming. The improvement in standards and the extension of services available is partially caused by a growing commercialization of healthcare service [24, 28]. Desired elements of interior arrangement include accessible bathrooms, high quality finishes, kitchen annexes allowing to prepare a simple drink or dish by the visitor or patient, quality bed linens, pleasant smell and lightning. The home away from home attitude of modern hotels, thanks to departure from traditional health facility design, helped improve the arrangement and contributes to lowered environmental stress and positively impacts the patient's condition [7]. Other small elements may also improve the overall mood, such as live flowers, magazines or a simple greeting screen on the bed's control panel.

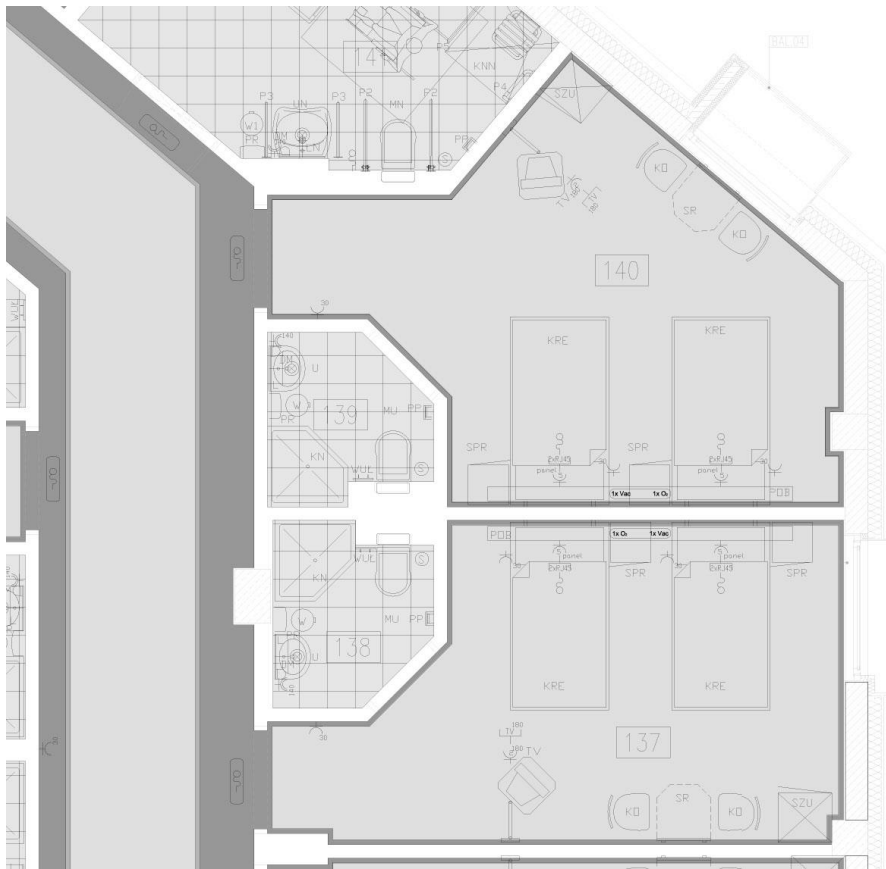


Fig. 1. Spatial arrangement of two bed rooms in the Swissmed Hospital, Warsaw, designed by Grupa 5
Source: students' work.

Room standardization contributes to improved work effectiveness but there also is a need to personalize patient areas. It is directly related to the already mentioned need to control the surroundings. There are several easy solutions such as wall mounted message boards displaying messages directly to the patient.

Another feature worth looking into is hybrid furniture like an adjustable chair allowing the patient to spent time outside of bed.

Several researchers corroborate the relation of colour to the wellbeing of human in the setting of healthcare facility [22]. In addition to colour itself the choice of material is also important. Natural high quality materials such as stone, wood are associated with the feeling of stability and durability. However, the basic need is to maintain hygiene and therefore to employ solutions limiting the growth of bacteria and facilitating disinfection (e.g. wood impregnating agents with silver ions). Infections are constantly an important problem for the healthcare.



Fig. 2. Spatial arrangement of one bed rooms in the Swissmed Hospital, Warsaw, designed by Grupa 5
Source: students' work.



Fig. 3. Spatial arrangement of one bed rooms in the Swissmed Hospital, Warsaw, designed by Grupa 5
Source: students' work.

The most common path of infection transmission are unwashed dirty hands. Wash basins and sinks are a standard now but it is still difficult to make people use them. The wash area should be equipped with non-contact taps and soap dispensers, single-use tissue bin and dirty linen bin. The use of high quality finish materials, which are washable and esthetic strengthening the feeling of stability, cleanliness and safety. The only solution to encourage the staff and patients to use the wash sinks is their attractive arrangement and design.

In the majority of Polish hospitals, patient bathrooms are located near the corridor wall. One of the benefits of such arrangement is the possibility for easy plumbing installation, leaving room for other arrangements like windows in the outside wall. In modern projects the sanitary facilities are also positioned along the outside wall speeding up access to the patient from the communication route (corridor). Such arrangement allows for functional space solutions to be located near the entry to the room.

In accordance with the technical construction legal requirements sanitary facility's door needs to open outside. It is recommended to pay attention to leaving enough room in front of the door for easy access in case a patient collapses in the bathroom. From the point of view of nursing personnel the size of the bathroom should be enough to accommodate for patient with a walking aid or wheelchair and an assisting person. All bathrooms should be equipped with rails and supports. The best bathing solution is a low profile or floor shower basin in minimal size of 90 x 90 cm equipped with a seat and a heavy curtain.

Family area

O Currently the hospital's approach to visitors and family is revised. The presence of family and close friends is an important component of the recovery process. Bed wards with space for visitors or family have better therapy results, since the relatives are often familiar with the therapy's details and are involved in the recovery process.

Unfortunately Polish hospitals are often lacking in this respect and their bed wards do not have enough space left for the visiting family or friends. Ideally there would be enough space to provide a possibility for private conversation. Such social spaces are often outfitted with a self service buffet.

Conclusion

We live in an individualized society , the modern humans are afraid of being dependent on other people, being disabled. Hospital are a place where our valued intimacy is being affected. These are the buildings where we often realize our own imperfection and mortality.

Can architecture influence the process on the recovery, and to what extent? Multiple studies have confirmed positive effects of comfortable functional and aesthetic ward arrangement, including the patient rooms [2, 14, 20, 36]. Poor funding of the healthcare system coerces savings in the designing and planning phases of the construction project. The haste in which they are implemented often results in insufficient analysis of possible consequences. Old solutions are being used and the finish quality suffers as funds are scarce. Popularization of the EBD method among the managers and designers of healthcare facilities could bring better effects and positively influence modernization work being done on hospitals and other facilities.

In modern process of designing of the healthcare facility, main accent needs to be put on correct functional solutions, optimizing personnel's work conditions and providing visually attractive interiors, since it is related with a positive impact on the patient's process of recovery.

References

- [1] **Aleksander, Ch.:** A Pattern Language. Town Building Construction, Oxford University Press, 1977.
- [2] **Andrade, C.C., Devlin, A.S.:** Stress reduction in the hospital room: Applying Ulrich's theory of supportive design, *Journal of Environmental Psychology* March 41, 2015, 125-134.
- [3] **Andrzejczak, R., Witczak, I.:** Jakość opieki zdrowotnej a ryzyko błędu ergonomicznego, [in:] Błąd medyczny. Uwarunkowania ergonomiczne. Eds. J. Pokorski, J. Pokorska, M. Złowodzki, Wyd. Komitet Ergonomii przy Prezydium PAN, Kraków, 2010, 107-120.
- [4] Arbeitsplatz Krankenhaus. Gesundheitforderliche Massnahmen fur Personal, (Assistance: Franz Labryga), Berlin 1993.
- [5] **Atkinson, J. Hohenstein, J. McCullough, C.:** Using evidence-based strategies, *Healthcare Design*. May 2011, Vol. 11, Issue 5, 2011, 47-54.
- [6] **Donetto, S., Penfold, C., Anderson, J., Robert, G., Maben, J.:** Nursing work and sensory experiences of hospital design: A before and after qualitative study following a move to all-single room inpatient accommodation, *Health & Place* 46, 2017, 121-129.
- [7] **Edmundson, K.:** Five need-to-know trends shaping healthcare design. *Healthcare Design*. Jul2011, Vol. 11, Issue 7, 2011, 24-27.
- [8] **Gawlak, A.:** Evidence-based design in healthcare facilities, [in:] *Architecture & Health*. Ed. Ewa Pruszczyk-Sipińska, Wyd. Poznań University of Technology, Poznań 2015, 30-31.
- [9] **Gehl, J.:** *Life Between Buildings: Using Public Space*, Washington - Covelo - London, Island Press, 1987 (2011 revised ed.)
- [10] **Huisman, E.R.C.M., Morales, E.J., Van Hoof, J. & Kort, H.S.M.:** Healing environment: A review of the impact of the physical environment. *Building and Environment*, No. 58, 2012, 70-80.
- [11] **Iyendo, T.O., Uwajeh, P.C., Ikenna, ES.:** The therapeutic impacts of environmental design interventions on wellness in clinical settings: A narrative review, *Complement Ther Clin Pract.* 24, 2016, 174-188.

- [12] **Jacobs, J.:** The Death and Life of Great American Cities, 1961.
- [13] **Juraszyński, J. et al.:** Projektowanie obiektów służby zdrowia. Arkady, Warszawa 1973.
- [14] **Makowiec-Dąbrowska, T., Sprusińska, E., Krawczyk, P., Józwiak, Z., Sitarek, K.:** Jak stworzyć bezpieczne i zgodne z zasadami ergonomii warunki pracy dla personelu kobiecego w zakładach służby zdrowia, Instytut Medycyny Pracy im. Prof. dra med. Jerzego Nofera, Łódź 2000.
- [15] **Malkin, J.:** A Visual Reference for Evidence-Based Design, Center for Health Design 2008.
- [16] **Malkin, J.:** The business case for creating a healing environment, Cent. Health Des. Bus. Brief. Hosp. Eng. Facil. Manag., 2003, 1-5.
- [17] **Meuser, P.:** Hospitals and Health Centers Constructions and Design Manual, DOM Publishers, 2011.
- [18] **Niezabitowska, E., Niezabitowski, A.:** Badania jakościowe w architekturze i urbanistyce, Zeszyty Naukowe Politechniki Śląskiej, Seria Architektura z. 33, Nr kol. 1344, 1996, 77-86.
- [19] **Niezabitowska, E.:** Od POE do BPE, Zeszyty Naukowe Politechniki Śląskiej Seria: Architektura z. 47, Nr kol. 1787, 2008, 143-157.
- [20] **Orłowski, J., Ealkowski, A., Złowodzki, M.:** Aspekty ergonomiczne w projektowaniu funkcjonalno-przestrzennym szpitali, Błąd medyczny. Uwarunkowania ergonomiczne. Eds. J. Pokorski, J. Pokorska, M. Złowodzki, Wyd. Komitet ergonomii przy Prezydium PAN, Kraków, 2010, 331-353.
- [21] **Pokorski, J.:** Ergonomiczne uwarunkowania błędów medycznych, [in:] Błąd medyczny. Uwarunkowania ergonomiczne, red. J. Pokorski, J. Pokorska, M. Złowodzki, Komitet Ergonomii przy Prezydium Polskiej Akademii Nauk, Kraków, 2010, 205-224.
- [22] **Pokrzywnicka, K.:** Barwa i jej wpływ na architekturę, [in:] Projektowanie i programowanie obiektów służby zdrowia, cz. 1, Wydawnictwo Politechniki Gdańskiej, Gdańsk 2012, 9-26.
- [23] **Ponikło, W.:** Infrastruktura techniczna szpitala, ABC Wolters Kluwer business, Warszawa 2010.
- [24] **Raeisinafchi, C.S., Mody, M., Guarracino, G.:** Hospitality Healthscapes: The New Standard for Making Hospitals More Hospitable. Boston Hospitality Review, Vol. 5, Issue 2, School of Hospitality Administration, 2017.
- [25] Szpitale w latach 70. Architektura, based Riba Journal, 1964, 1967, 219-222.
- [26] **Ulrich, R.S.:** Effects of interior design on wellness: theory and recent scientific research, J. Health Care Interior Des., 3 (1), 1991, 97-109.
- [27] **Ulrich, R.S., Zimring, C., Zhu, X., DuBose, J., Seo H.-B., Choi, Y.-S. et al.:** A review of the research literature on evidence-based healthcare design. Healthcare Journal. 2008, Vol. 1, No. 3, 2008, 61-125.
- [28] **Wu, Z., Robson, S., Hollis, B.:** The Application of Hospitality Elements in Hospitals, Journal Of Healthcare Management, American College Of Healthcare Executives, J Healthc Manag, 2013 Jan-Feb, Vol. 58 (1), Publisher Foundation of the American College of Healthcare Executives, 2013, 47-62.
- [29] **Złowodzki, M.:** O ergonomii i architekturze, Wyd. Politechniki Krakowskiej, Kraków 2008.
- [30] Regulation of the Minister of Health of 22 June 2005 concerning requirements that the facilities and equipment of healthcare center should meet (Journal of Laws 2005, No. 116, item 985).

- [31] Regulation of the Minister of Health of 26 June 2012 concerning detailed requirements that the facilities and equipment of entities conducting therapeutic activity should meet (Journal of Laws 2012, item 739).
- [32] Regulation of the Minister of Health of 28 December 2012 on the method of setting minimum standards for the employment of nurses and midwives in non-business entities (Journal of Laws 2012, item 1545).
- [33] www.hberm.com/wp-content/uploads/2015/10/HBN-04-01-Supplement-1-Isolation-facilities-for-infectious-patients-in-acute-settings-20131.pdf - accessed on 14.10.2017.
- [34] www.healthdesign.org/sites/default/files/Malkin_CH1.pdf - accessed on 10.10.2017.
- [36] www.nrls.npsa.nhs.uk/EasySiteWeb/getresource.axd?...type... - accessed on 12.10.2017.
- [35] www.rp.pl/Lekarze-i-pielegniarki/306139958-Pielegniarka-nie-powinna-miec-pod-opieka-wiecej-niz-6-8-pacjentow.html - accessed on 12.10.2017.

BACKYARD SENSORIMOTOR PATH. A NEW FORM OF REHABILITATION

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Abstract: The article describes an innovative solution designed within the framework of the “Lesser Poland Incubator of Social Innovation” project supervised by the Regional Centre for Social Policy in Krakow. The first stage of the project was completed in September and presented the methodology of the design, testing and possibilities of implementation of the solution that had been developed. It is an attempt to create a suitable housing environment that offers the opportunity to exercise in the immediate vicinity of one's home, outside but in a safe environment of recreational areas. Creating moto-sensory paths – friendly places of prevention and rehabilitation – within urban housing complexes, would positively affect the image of space, as well as the maintenance of the efficiency and quality of life of the inhabitants. This article describes the preliminary research phase required to create guidelines for designing such solutions. The backyard moto-sensory path is currently being tested.

Keywords: urban space, new forms of rehabilitation, rehabilitation of dependent persons.

Introduction. The sensorimotor space

Along with demographic changes there comes the problem of adapting urban spaces to the real needs of their users, needs that change over time. Currently available forecasts have shown that in many countries, including Poland, the years immediately ahead of us will be characterized by the largest increase of persons in the 65 years and older segment in terms of demographics. Motor and intellectual ability, as well as the capacity for spatial orientation, decrease with age. Over 70% of disabled persons are those that are older than 50. The decrease in physical and mental capabilities in seniors is often caused by disorders like Parkinson's or Alzheimer's Disease. The largest threat in the working age and post-working age group – seniors and the elderly – are the results of cardiovascular diseases. Statistically, 70 thousand Poles suffer a stroke every year – which leads to a weakening of the cardiovascular system due to insufficient blood supply or the penetration of the blood-brain barrier, which most often leads to a serious loss of health and permanent disability. Multiple

sclerosis is also a significant problem. According to statistics, around 60 thousand people, who are mostly in the working age group, suffer from it in Poland, causing them to be in danger of being excluded from public life, particularly due to gradually worsening mobility. The disorders that have been described require constant rehabilitation in order for a patient to retain mobility at a level that prevents the loss of self-sufficiency and social exclusion. The proposed solution features the creation of an appropriate residential environment that provides the possibility to perform exercises in the immediate vicinity of one's place of residence, outside, but in the safe surroundings of recreational areas. The establishment of sensorimotor paths – friendly places of prevention and rehabilitation in the space of the urban interiors of residential complexes – would positively influence the shaping and maintenance of physical fitness and the quality of life of residents. The development of stations, as well as the planning and construction of a path, require expert knowledge and experience in order for the offering to meet its intended goals. Improperly selected, annotated (or not annotated at all) or tailored stations can be not only ineffective, but can also produce a negative effect and be dangerous.

The design of the path to be developed, features all the necessary objectives and indications for entities who wish to construct one. The solution also includes the development of instructions for users and their caretakers - how to effectively use a path working as the “virtual coach”, choosing and conducting workout plans matching the condition of the user. The innovative nature of the project lies in its proximity to the place of residence, open use, creating possibilities of stand-alone, effective training.

The scientific goal of the project

The implementation of the project was divided into two phases: a preparatory phase, during which the method of the implementation of the innovation that is the subject of this paper was developed, as well as a testing phase. The scientific goal of the project's first phase was proposing a solution in the form of a training area in the direct vicinity of a house that can be used for training and improving or preserving one's fitness by dependent persons – seniors or disabled persons. The researchers focused both on functional aspects, tied with training effectiveness, as well as spatial ones that take into account the guidelines for the design of backyard sensorimotor paths. Simultaneously, the researchers tried to solve the problem of the motivation to use the solution thanks to the activation of dependent persons and their circles through creating a place that would encourage interpersonal relations, as well as the communal spending of time that can improve family relationships.

Research results

The urban space – a space of therapy

When in an urban space we are accompanied by sensorimotor elements. All structures that are contained within this space influence our senses in some manner, so practically any urban space is a sensorimotor space, which makes it possible to use it for the purposes of therapy by combining motor therapy with appropriate sensory stimulation, controlled through intensification or reduction.

The therapeutic properties of spending time in outdoor spaces, particularly in green surroundings, are widely known. Outdoor space encourages us to be active – as physical activity is necessary for correct human functioning. Just how important physical activity is has been shown by its placement at the foot of the nutrition pyramid published by the National Center for Nutritional Education in 2016.

At the same time, being outside is associated with receiving an immense amount of sensory stimuli, from which we are separated when inside buildings. Apart from what we see and hear; we feel changes in air temperature and of the surfaces that we touch, we can experience various smells, light changes during the day/night cycle, further varied by weather (including the external artificial lighting during the night). Of course, the array of signals that we receive will be different in natural surroundings from those in the center of a city. Stimuli that are therapeutically significant are both those that are generally received as desired (the so-called “sounds of nature”: the sound and splash of water, animal sounds, a light breeze, the sun's rays shining through the crowns of trees, the touch of soft grass or the fluffy fur of an animal, the smell of flowering plants or of baked bread, etc.), as well as those that we perceive as negative, e.g. the noise associated with transport – a dependent person very often spends their entire time in a room and getting used to the noise of the city in pleasant conditions can lessen the fear of open and loud spaces and the stress that is associated with it. The mechanism of the influence of public spaces on their users can also be used as a form of therapy. Residing in a given space that stimulates the senses in a controlled manner, combined with appropriate motor training, can beneficially impact the motivation of users, as well as the obtained results. It can also reduce fears associated with using a public space through the elimination, denial or adapting to negative sensory background stimuli (e.g. the noise of a street causing stress) through new ones – that refer to positive memories, from childhood, for instance [1, 2, 9, 12].

The sensorimotor path is meant to be a therapeutic space, in which both of these aspects will be combined with each other in a controlled manner through a selection of sensory stimuli and appropriate motor training adapted to a patient's condition. The most important objective, however, is providing an answer to modern demographic trends – the development of cities and the aging of society. This is why it is so important to “ease in” to urban space, as well as to

use it as a tool in everyday training that aids in preserving functional ability levels for as long as possible.

How the path works

It is assumed that human health largely depends, in the physical sense, on hereditary, dietary, emotional, psychological and environmental factors. The last three are ones that can be influenced by both architecture and the landscape. Living in a crowded city, where contact with the environment is limited, can have an impact on lowering the level of fitness in the elderly and the disabled through the elimination of a part of the stimuli that enhance the feeling of safety from the environment and replacing them with others that can cause exclusion through the lack of a sense of safety during traversing a public space. Another element is using existing conveniences that can cause laziness and the lack of continuous motor training.

We can influence user behavior by appropriately designing a space. Thanks to aesthetics and spatial order, we can attempt to support user choices by motivating them to train. This can be encouraged by the quality of a space, which can cause the viewer's interest. Floors, natural elements and objects that appear within a backyard space should enrich it and make it more attractive.

Motor training performed on the path does not require complicated machinery, as this area is meant to simulate an urban space. In it we encounter obstacles that are imperceptible to an average, fit person, but that create difficulties to seniors, disabled persons, and even to healthily developing children. This is why, in order to prevent discouragement, avoiding obstacles and - through doing so - functioning in a public space in an incomplete manner, which can gradually lead to exclusion, it is beneficial to perform continuous motor training in one's own backyard.

In order to create a friendly and attractive training space we should chiefly use those elements that allow us to familiarize ourselves with obstacles that cause us difficulties in everyday travel across urban space. First and foremost, these should be places associated with preserving balance, on an irregular surface, as well as an incline. Spatial elements should take into account scaling various heights and elevations using stairs, as well as fixed and moving platforms. Another important factor is the surface, which, particularly in an open space, depending on atmospheric conditions, will imitate various types of flooring encountered in an urban space (cobblestone, stone floors, soft surfaces, etc.). Irregularity, slipperiness and even slushiness can cause difficulties. Awareness of one's own motor limitations often causes a fear of moving in more difficult conditions among patients, and it is something that can be eliminated by training in one's own backyard space.

Apart from the shape of the terrain, the use of natural elements – greenery and water – will also be key. They will fulfill sensory functions, affecting the senses of hearing, touch, smell and taste. It is also possible to introduce elements

of hortotherapy (e.g. the planting of bulbous plants, etc.), which can aid in the social function of the established place – the sensorimotor path.

Where needed, apart from the shape of the terrain and natural elements, the design will implement simple machinery through which platforms featured in the design can be moved (like in the case of a carousel, or spring-mounted platforms imitating standing in vehicles during travel. They will also constitute a supplementation of the basic structure of the path, which will mostly be based on the creation of an appropriate topography.

The entirety should be concentrated in a small area, based on the multi-functionality provided thanks to comprehensive instructions. Each individual element can serve the performance of numerous exercises and be used to create new exercise stations.

Thanks to the proper design of the sensorimotor path, it will be possible to use it in various ways in order to integrate various target groups. This will play a therapeutic role for seniors and the disabled, improving a patient's condition through rehabilitation. At the same time, the path can be the site of attractive walks for able persons and children. Through communal care for its aesthetics and condition, it can become a site that improves family relations, and can also be conducive to social contact. It can become an area for the exchange of experiences between dependent persons and their caretakers.

Sensory elements

Multisensory stimulation is the basic task of a space with sensory therapeutic properties. Stimulating all the senses provides persons with limited abilities whose sensory perception is limited in either one sense or a group of senses, with the possibility of therapy. Basic goals for the use of sensory paths during training were outlined: familiarization with urban space through building up a sense of safety through gradual training and referring to pleasant experiences in order to enhance self-confidence in dependent persons.

Sight. In research conducted within an urban space one aspect that is important is the fact that a user, when performing tasks, can simultaneously observe and be observed, which can initially affect their discomfort (shyness). This is why it is necessary to provide stations with varying degrees of spatial enclosure. Initially, the link with the surroundings can be provided only through other senses, and as the training progresses, this space should be gradually opened to building up a sense of belonging to the local community that uses the surrounding spaces, as well as to provide safety of use. The second important factor is lighting. The feeling of intimacy and safety depends on its intensity at the site where training is performed. One of the path's design objectives will be the possibility of gradually increasing exposure to stimuli that are compliant with the training program of familiarization with urban space.

Hearing. Just like in the case of the sense of sight, it is important to ensure a gradual exposure of a user to audio stimuli, which will make it possible to

facilitate a sense of safety. This can be provided by decreasing the volume of natural sounds and introducing stronger and stronger stressful audio stimuli that imitate the sound of traffic.

Smell. Taste. Stimulating the senses of smell and taste thanks to aromatic and edible plants will mainly be based on building self-confidence associated with reference to positive experiences and then the gradual elimination of these stimuli.

Touch. With the help of touch, textures and perceivable temperature we can also control experiences that aid motor training and cause referral to memories. Such stimulation will also be of significance in the process of memorizing a task, as well as in orientation within an urban space.

Sensory stimulation will also be performed in the case of persons with deficits in any of the senses, which can help in the preservation and even improvement of the condition of a dependent person. Theoretical elements can also aid in independent evaluation of perception in a dependent person and help in diagnosing deficits in a quicker manner.

Test group selection criteria

The researchers intend for dependent persons – with varying degrees of disability and different illnesses and disorders, whose condition indicates motor limitations of varying degrees and the associated difficulties in using urban public spaces – to be involved in the testing phase of the sensorimotor path model. The final group is to contain persons that are excluded from being able to fully make use of public spaces or those that are in danger of facing such exclusion. The condition for participation in the tests is the ability to move independently (the model that will be tested will not be targeted at people who depend on wheelchairs for transport, although the possibility of including this implementation in the final model is not ruled out), and a degree of disability that makes it possible to perform the easiest variants of exercises.

9 persons will participate in testing the model. Five of them will be disabled persons with varying degrees of disability and different disorders and illnesses. The four additional persons participating in the test group will be senior persons that are over 65 years of age. When selecting persons assigned to training on the prototype sensorimotor path, their level of functional ability was taken into account. This type of fitness is understood as the ability to perform activities of daily living in a manner that is as safe and independent as possible, with optimal energy use (without excessive fatigue). Limitations are usually present in the performance of complicated tasks. This applies both to persons afflicted by disability, as well as the elderly. Complex tasks are those that are associated with the performance of house chores, professional activity and the operation of equipment. As time goes by (e.g. in the case of seniors; those suffering from multiple sclerosis) they gradually encroach to the area of basic tasks associated with self-sufficiency in the immediate surroundings – in bed, in the bathroom,

the kitchen, the apartment. The concept of the sensorimotor path is aimed at increasing the functional ability of users.

In light of the above, in order to assess functional ability in terms of everyday tasks, the authors used the Barthel Index, which has been attached as an appendix. The deciding factor in the selection of persons qualified for training was the detailed interpretation of its results. Persons in the III score group were not taken into account. Lawton's scale (IADL), which refers to the assessment of complex activities of daily living, was also used during the process of qualification for the testing phase. The qualification threshold for the testing phase was assumed at a score level of at least 12 points.

The screened group of disabled persons with varying degrees of disability and different disorders and illnesses were the patients of the Day Care Rehabilitation Ward of the University Hospital in Krakow. The assessment was performed by a qualified physiotherapist, who is an employee of the University Hospital. Seniors were qualified using the same criteria, while the screening group consisted of the attendees of the University of the Third Age that operates beside the Agricultural University in Krakow. At the same time, the Barthel Index was used to assess the degree of self-reliance, as a tool for the verification of the usefulness of functional training on the sensorimotor path.

The diversity of dysfunctions that the persons that made up the test group were characterized by was dictated by the possibility of obtaining a more complete picture of the functionality and effectiveness of the stations. Thanks to this approach, the path will be more universal and can be used by wider groups of users – dependent persons.

Description of motor training

The sensorimotor path combines within itself many elements, through which it provides a holistic form of therapy. Depending on individual needs and indications, it allows the performance of comprehensive motor training. It can be used as a supporting tool in the tiresome and often years-long process of rehabilitation. The ideal solution is designing the path in such a manner so that it can serve dependent persons, but also as a recreational form of spending free time, constituting an attractive form of competition for modern forms of entertainment and recreation. One particular benefit of the path is its location – directly adjacent to one's place of residence, which makes it possible to save time associated with driving into a similarly attractive place, and thus it highlights its common accessibility.

In the context of dependent persons it would be good to mention that such a solution ensures the continuity and wide accessibility of rehabilitation, which is a significant and often key element of the process of treatment and recovery. Dependent persons, burdened by chronic illnesses, require integrated rehabilitative care in order to maintain or, if possible, improve their comfort of living. Situations in which these persons do not have the necessary conditions to

continue their therapeutic program outside of specialist physiotherapy facilities are not uncommon. Such a state of affairs leads to a lowering of the level of ability and a regression in relation to the effects that were obtained during work with a physiotherapist. This makes it all the more important for the sensorimotor path to constitute an equivalent of a backyard training facility, and allow a fluid continuation of training motor strategies.

Apart from training stations, the area of the sensorimotor path will also include decorative, aromatic and edible plants that will constitute a supplementation of therapeutic functions through the stimulation of appropriate centers within a path user's brain, in order to strengthen the potential for plasticity that is being released and to stimulate the process of the reconstruction of neuronal connections [7, 12]. This phenomenon is particularly desired in the case of persons with neurological dysfunctions, e.g. those that had been through a stroke. Experiencing pleasant sensorimotor experiences strengthens a patient's motivation to further fight for their self-reliance and increases their self-confidence. Such an approach establishes the path as a significant socialization tool that eliminates the feeling of exclusion. The therapeutic goal of the sensorimotor path is the working out of optimal functions that can serve to attain the goal outlined by the task, in specifically determined environmental conditions. All of this is meant to ensure that everyday difficulties can be efficiently overcome, new functions can be obtained and that external help is limited to a minimum. Basing on positive motor experience, a neurologically affected person is capable of developing proper motor patterns and strategies [5, 6, 7, 16].

The path is meant to create the ability for variation in training – special markings will not only inform about how exercises are to be performed or the function that they play, but will also suggest to the users for whom a given route is addressed and how to modify an exercise in order to obtain a higher or lower level of difficulty.

The path that is being designed will meet the objectives of sensorimotor integration and, in some manner, familiarize users with stimuli that are irritable to them. One example is a person that has suffered a stroke and which shows symptoms of hypersensitivity to smells that appear in their surroundings, causing positive, but more often negative reactions of the organism (e.g. nausea, lightheadedness). A healthy person, in the case of exposure to these types of stimuli, remains unaffected, and the eventual reaction of the autonomic nervous system is not as heightened. The objectives of the sensorimotor path take into account the gradual exposure of users to the aromatherapeutic effect of plants, which is meant to directly lead to adaptation to irritating stimuli. Another example can be the case of a person who cannot accept changes in the surface on which they travel. Such a state of affairs is a reason to introduce this aspect to the path and use available materials in order to create a diverse surface, so that a user can be gradually exposed to an irritable stimulus – just like in the case of hypersensitivity to smells. Thus, a part of the elements will be accessible without the necessity to put on shoes, in order to enable the gathering of proprioceptive

information by the largest possible surface of the foot. The sensorimotor path is meant to be located in one's own backyard, which constitutes another therapeutic support for persons that are hypersensitive to noise. This is particularly important to persons that have suffered a stroke, who have significant difficulties in focusing on the task that they are performing [3, 4, 5, 12].

The concept of the path will largely be based on motor strategy training. A substantial element of the outline of such motor strategies is motor control. It includes the mutual operation of the musculoskeletal and nervous systems. The goal of motor control will be the planning and then the economic and flawless execution of a motor task (obtaining the ability to regulate or direct the necessary mechanisms of motion). Tasks aimed at improving the factors that affect motion control will be performed during work with an activity trainer. The concepts that were developed will be modified during later stages and adapted to the capabilities of users, so that training will be possible to perform without the participation of a specialist [7, 8, 10, 15].

One of the main objectives of training on a sensorimotor path is also obtaining an improvement of posture control. It is the dynamic ability to counter gravity depending on the position of the body within a space and a changing support surface. It directly transfers to the ability to maintain and retain balance. At the same time, the path will very strongly work towards retaining/maintaining balance at a stable level of eccentric control of anti-gravitational muscles, which condition the control of the speed of performing a motion. In order to attain these goals, techniques that improve endurance and eccentric activity, dynamic stability and flexibility will be used [3, 4, 7, 11, 16].

The featured activities will also have the goal of improving proprioception (the orientation of the body within space), which is particularly distorted in persons that have suffered a stroke. Proprioception is responsible for the proper performance of several activities of daily living. This mechanism allows us to plan basic motor strategies, such as walking. Planned exercises will be conducive to the improvement co-contraction, which is the ability to deliberately contract antagonist muscles (flexors and extensors) so that balance can be maintained. The goal of exercises performed on the sensorimotor path will not be the elimination of a pathological motor pattern, but the frequent repetition of a functional adaptation strategy in such a manner that it can be used with more confidence, agility and effectiveness [7, 11].

Apart from the tasks mentioned before, the path, as a therapeutic tool, will counteract mobility loss. Patients are struggling against the loss of muscular strength, stiffness and pain every day. Not using one's limbs results in the loss of motor representation, which transfers to a growing deficit of muscular strength. What is important, the simple subjective feeling of pain leads to a loss of motor representation. We thus arrive at a vicious circle – pain discourages activity – the lack of activity increases pain. The sensorimotor path features activities that are selected to counter the abovementioned degenerative alterations and encourage physical activity that will be prepared in an interesting, attractive and functional manner [3, 7, 8, 16].

A very serious problem that affects persons with central nervous system damage is the phenomenon known as spasticity. It is defined as excessive resistance to the extension of a muscle [11, 16].

Repeating functional and strength training that is proposed by the path leads in such cases to a reduction of spasticity by the means of improving neuromuscular coordination, which is considered the cause of muscle stiffness. Thus, the sensorimotor path as a method that supports dependent persons, directly leads to improving the comfort of living, because reduced spasticity means a higher range of motion, precision and speed [16].

The process of aging is associated with a series of structural and functional changes: a reduction in non-fat body mass, the loss of strength and flexibility of muscles, tendons and ligaments. Furthermore, aerobic capacity is significantly reduced in older persons. These are the main pathophysiological changes of, among others, balance disorders that result in an increased risk of falling down. This, on the other hand, leads directly to dependency on other people and, further, to disability. Latest research indicates that it possible to increase muscle mass and strength through the use of strength training by the elderly – even those of very advanced age. Physical activity by the elderly positively affects such motor qualities like suppleness, balance and motor coordination. The use of strength training and balance exercises leads to the improvement of the quality and speed of gait. Balance exercises are substantial in the prevention of falling, and suppleness can make activities like dressing up and undressing easier [6, 10, 14].

Functional training with elements of strength and aerobic training is an appropriate and safe method of improving not only the effectiveness of the musculoskeletal system, but also the cardiovascular one as well. It reduces the risk of such disorders like diabetes, osteoporosis, atherosclerosis, hypertension or pathological changes in the pulmonary system and disorders that affect the brain, such as Alzheimer's disease. The influence of training on the nervous system of a senior person is thus not without importance. Its proper functioning is shaped in connection with physical activity. Scientific research indicates that physical activity leads to an increase in the amount of neural connections within the brain through the increase and improvement of the transport of oxygen to its cells [6]. It is thus a form of preventing Alzheimer's disease. It is widely believed that maintaining cognitive activity and learning processes is mainly performed through high intellectual activity (the solving of crosswords, reading books, etc.), meanwhile it is physical activity and, simultaneously, a high supply of oxygen to the neural cells of the brain that result in maintaining an optimal level of psychological health. The brain's cognitive abilities become improved, along with a lessening of emotional instability and better overall wellbeing. A better psychological condition and wellbeing in turn lead to a statistically higher amount of senior persons that are more eager to actively participate in public and cultural life. Physical activity also improves the functioning of the respiratory system. The benefits feature improved respiratory ventilation, the mobility of the chest, the flexibility of the breathing muscles, the ability to

breathe in deeper, breathe out longer and cough effectively, which often constitutes a serious problem among seniors. Systematic training also has a beneficial impact on the immune system of seniors. Moderately intense exercise causes changes in immune mechanisms. They include, among others, increasing the amount of serum antibodies. Thus, an increase in the level of physical activity in seniors can lead to a decrease of episodes featuring symptoms of respiratory tract infections [6, 12]. In seniors, it is important to motivate them to train by making them aware of the benefits that regular activity brings, which is why the stations of the path, apart from instructions, will also contain information with the description of how a given exercise works.

To sum it up, regular exercise makes it possible not only to maintain physical fitness at an appropriate level, but also postpone the necessity to become dependent on the help of others. Aging is one of the many risk factors for disability. Furthermore, the lack of physical activity or its insufficient amount leads to the development of degenerative changes and deformations, osteoporosis and thus the brittleness of bones. These processes can be postponed by maintaining physical activity into very old age. The positive impact of physical exercise is particularly visible in the improvement of the technique, coordination, speed and autonomization of movements that are necessary in situations of everyday life, which has been described earlier [14, 15].

Methods of verifying training effectiveness

The method of verifying training effectiveness will be based on motor and psychological tests, both initial and final, performed after a training session on the sensorimotor path. They will be performed in a uniform setting at the Rehabilitation Department of the University Hospital in Krakow. They will constitute the initial assessment of the tested persons and will allow for an objective verification of the usefulness and functionality of each of the stations of the sensorimotor path. The initial and final diagnosis will be performed using the following tests: Lawton's Scale (IADL)¹, the Barthel Index², the "Timed up and go" test³, POMA⁴, the Clinical Test for Sensory Interaction in Balance (CTSIB)⁵, the Functional Reach Test⁶ and the 6-Minute Walk Test (6MWT)⁷.

¹ Lawton's Scale (IADL) – used to assess complex activities of daily living.

² Barthel Index (Modified Barthel Scale) – used in the general assessment of the degree of self-sufficiency (or its change over time) as a tool that is used in the initial assessment of persons that are assigned for training on the sensorimotor path and that verifies the usefulness/functionality of the entire training process.

³ The TUG test – the timed „up and go” test) – a test based on the assessment of basic activities of daily living: assuming a standing position from a sitting position, marching a short distance (equal to the average length of a pedestrian crossing), turning around by 180 degrees and assuming a sitting position from a standing position.

⁴ (POMA-B) – contains in it 9 qualities regarding assessing balance when sitting, standing up, in a standing position, when rotating and sitting.

Psychological tests will be performed using the pen and paper method. Every participant of the project will be given a set of questionnaires to fill out before the project's impact begins and after it has finished. The set is composed of two standardized psychological tools, the State-Trait Anxiety Inventory (STAI)⁸, the Generalized Self-Efficacy Scale⁹ and a questionnaire designed for the purposes of this project.

Conclusion

According to the World Health Organization, the definition of quality of life is conditioned by one's health, and refers to functioning in the physical, psychological and social spheres, in addition to being subjectively assessed by an individual. The concept of quality of life is complex and can be defined from various perspectives. Physical activity, which is one of the indicators of one's lifestyle, is of substantial importance both to the physical and psychological sphere. As a result of the advancement of technology, humans have decreased their physical activity, leading to a reduction in their physical capacity. In light of the above, in the case of older people it is particularly important to preserve good physical and psychological condition through maintaining appropriate physical activity that is a permanent part of one's lifestyle. Systematic, pro-health training is a significant element of one's lifestyle that conditions good health and considerably increases its quality in the case of persons with neurological disorders.

Improving one's health or maintaining one's fitness usually lays at the foundation of a person's motivation for physical activity. On the other hand, the high cost of participating in its diverse, organized forms can form an obstacle. The design of the sensorimotor path goes against these limitations through its commonly accessible form of placement in one's own backyard.

(POMA G) – contains in it 7 qualities that assess gait taking into account its start, the length and height of the stride, the symmetry of steps, the continuity of gait, the path of walking and the position of the body.

⁵ Clinical Test for Sensory Interaction In Balance (CTSIB) – an assessment of balance in various sensory conditions with the use of frontal lobe and proprioceptive information.

⁶ (FR –Functional Reach Test) – a test of functional reach that assesses the risk of falling down.

⁷ 6-Minute Walk Test (6MWT) – a test that refers to physical endurance.

⁸ State-Trait Anxiety Inventory – STAI – is a tool meant to assess anxiety that is understood as a temporary and situationally conditioned state of an individual, as well as anxiety understood as a relatively permanent personality trait. This scale is considered useful in experimental research to register changes in the intensity of anxiety [after: <http://www.practest.com.pl/stai-inwentarz-stanu-i-cechy-leku-stai>].

⁹ The Generalized Self-Efficacy Scale – GSES – measures the general conviction of an individual about their efficacy in dealing with difficult situations and obstacles [after: <http://www.practest.com.pl/gses-skala-uogolnionej-wlasnej-skuteczności>].

However, the lack of the habit of spending one's free time in an active manner and the lack of acquaintances who are interested in such forms of activity can lower motivation. In this case, an interesting and functional form of exercise using a sensorimotor path can constitute additional motivation, and clear instructions placed near its stations and the variation in difficulty level should encourage one to take up the challenge not only in a group, but individually as well.

The preparatory stage of the project laid basis for architectural design and development of practice stations as well as it was necessary to create the virtual coach application. The following stage, that is to be finished by the end of February 2018 is going to bring specific design solutions and conducting further research in this field.

References

- [1] **Bauman, R.:** Domy w zieleni. Arkady, Warsaw 1991.
- [2] **Benek, I.:** Ogrody terapeutyczne dla osób starszych, <http://www.forumprzestrzeniemiejskie.pl> – accessed on 08.01.2017.
- [3] **Campbell, E., Elaine, M.R., Coulter, H. et al.:** Physiotherapy Rehabilitation for People With Progressive Multiple Sclerosis: A Systematic Review, *Phys Rehabil Med*, 97(1), 2016, 141-151.
- [4] **Conradsson, D., Löfgren, N., Nero, H.:** The Effects of Highly Challenging Balance Training in Elderly With Parkinson's Disease, *Neurorehabil Neural Repair*, 29(9), 2015.
- [5] **Czarnecki, K., Gedacd, Y.E., Seimec, R.:** Functional movement disorders: Successful treatment with a physical therapy rehabilitation protocol, *Parkinsonism Relat Disord*, 18(3), 2012, 247-251.
- [6] **Halvarsson, A., Franzén, E., Ståhle, A.:** Balance training with multi-task exercises improves fall-related self-efficacy, gait, balance performance and physical function in older adults with osteoporosis: a randomized controlled trial, *Clin Rehabil*, 29(4), 2015.
- [7] **Horst, R.:** Trening strategii motorycznych i PNF, Wydawnictwo TOP SCHOOL, Krakow, 1st edition 2010.
- [8] **Kwak, D., Uk Ryu, Y.:** Applying proprioceptive neuromuscular facilitation stretching: optimal contraction intensity to attain the maximum increase in range of motion in young males, *J Phys Ther Sci*, 27(7), 2015, 2129-2132.
- [9] **Latkowska, M.J., Miernik, M.:** Ogrody terapeutyczne – miejsca biernej i czynnej „zielonej terapii”, *Czasopismo Techniczne*, Wydawnictwo Politechniki Krakowskiej, 8-A/2012, Vol. 30, 2012.
- [10] **Mesquita, L., Carvalho, F., Freire, L. et al.:** Effects of two exercise protocols on postural balance of elderly women: a randomized controlled trial, *BMC Geriatrics*, 15(61), 2015.
- [11] **Olak, K., Kloda, M., Szlufik, S. et al.:** Evaluation of health restoring progress in ischemic stroke patients within acute and subacute period applied with PNF therapy components, *The Journal of Academy of Physical Education Warsaw*, Published online: 2016-05-06 | DOI: <https://doi.org/10.2478/rehab-2014-003>

- [12] **Pollock, A., Marshall, M.:** Designing outdoor spaces for people with dementia; Hammond Press, Sydney 2012.
- [13] Poznan University of Life Science, <http://www.hortiterapia.edu.pl> - accessed on 20.01.2017.
- [14] **Someshwar, H.P., Kunde, C., Ganvir, S.S.:** Predicting the probability of falls in geriatrics using traditional timed up and go test and dual-task constraint timed up and go test: An observational study, *Int J Health Allied Sci*, 6(2): 88-92 (2017).
- [15] **Singh, O.P., Gaurav, S., Saraf, S.K.:** The effect of “Structured Neuro-muscular Postural Training” in balance modulation and fall prevention strategy in osteoarthritis knee, *JESP*, 11(1), 2015.
- [16] **Wang, J.S., Lee, S.B., Moon, S.H.:** The immediate effect of PNF pattern on muscle tone and muscle stiffness in chronic stroke patient, *J Phys Ther Sci*, 28(3), 2016, 967-970.

ERGONOMIC AND FUNCTIONAL ANALYSIS OF THE INTEGRATED THERAPEUTIC ENVIRONMENT, GUIDELINES AND IMPROVEMENT CONCEPTS

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Abstract: The article presents the concept of integrated system of the therapeutic environment focused around people with autism spectrum disorder. The analysed topic is presented from various points of view – focusing mainly on therapists and children. The basis for solving the problems observed are designs of robots which support therapy and which are attractive for children, but first of all the programming solutions that impact the therapists' work comfort in a positive way.

Keywords: autism, rehabilitation tools, occupational burnout among therapists, robots.

How ergonomic product designing can be useful for therapy of people with autism?

Designing is often defined with the word design and commonly seen as limited to attractive exterior look of the objects which surround us and which are created. When buying a new product, the user more and more often seeks “designer” things, i.e. beautiful, expensive, and exclusive. However, the design which can be studied at different Academies of Arts in Poland focuses on many more aspects – reaching deeper into the structure of the designed products. Responsible designing is mainly about creating objects which are useful, needed, which solve real and important problems [9]. Materials and technologies used in manufacturing as well as the look of the products are obviously significant, but they cannot be superior to their utilitarian functions and in case of rehabilitation tools their practicality [6]. The Design Ergonomics Laboratory/Workshop found at the Faculty of Industrial and Interior Design at the Strzemiński Academy of Art in Łódź in its educational curriculum assumes first of all searching for design solutions focused on widely-understood users' needs. In response to

constant demographic and structural changes in our society, the topics for design and research which are currently being developed centre around the needs of the elderly and the disabled. In 2015 as part of co-operation with the Institute of Robotic Control of the Institute of Automatic Control at the Faculty of Electrical, Electronic, Computer and Control Engineering at Lodz University of Technology and Navicula Foundation the students' designing activities were aimed at problems of people with autism and the people around them.

Is there space for designing in therapy of autistic people?

From the point of view of an emphatic designer the answer must be positive. Another confirmation of the thesis are the positive effects of the co-operation within the scope of complex designing of therapeutic tools. Initial recognition of the rehabilitation process allowed us to assume that interdisciplinary teams can offer practical solutions for the most common problems. It quickly turned out that together we can design things that are useful, safe, with broad utility process, made of durable materials and obviously attractive in form. The trilateral co-operation made it possible for teams from Lodz University of Technology and the Strzemiński Academy of Arts to deeply analyse the environment of autism therapy in the seat of Navicula Foundation. Students and teachers had the opportunity to participate in chosen therapeutic classes and lectures which depicted the issues of autism and therapy of those who suffer from it¹.

Autism? What is it?

In order to analyse the process of therapy it was first of all necessary to understand the issue of autism and getting familiar – even if superficially – with a wide range of behaviours which are symptoms of the disorder. Since the moment the UN announced 2nd of April to be the World Autism Awareness Day the knowledge about what autism is gets more and more popular. It makes it easier to understand better what kind of difficulties are encountered by those who suffer from ASD and their closest family and friends. Most of us already know that an autistic person avoids eye contact and does not like to be touched, but these are only small symptoms which do not have to hinder relations with the world. It is definitely more important from the point of view of designing for

¹ All projects of toy-robots were carried out within interdisciplinary classes for student form – Wszystkie projekty robotów-zabawek zostały zrealizowane w ramach zajęć interdyscyplinarnych łączących studentów WiAW ASP i IAZSR PŁ.

Projects were accomplished under the supervision of dr hab. Anna Miarka (Academy of Fine Arts), dr hab. inż. Grzegorz Granosik (Lodz University of Technology) and mgr inż. Igor Zubrycki (Lodz University of Technology) in academic years 2014/2015, 2015/2016, 2016/2017.

people with autism to recognise the ways in which they see the world. It turns out that it is undeniably more complicated than it might seem. Most often such people appear to be very focused on themselves, as if distant, bemused and they repeat sentences or words after the preceding speaker. They seem indifferent to the surroundings and behave inadequately to the situation they are in [8]. They put objects or toys in non-typical and surprising ways, they can talk about one subject for a very long time and they are clearly fascinated with it. They can throw tantrums or be in a bad mood without any clear reason. Children often express their needs by using the hand of an adult. One of the most common behaviours of people with autism is striving for monotony. It is also easy to notice fear in their behaviour or even resistance against any changes [8], this is why routine is very important in everyday life – the same activities, the same interiors and their equipment [21]. However, one of the most significant problems is the lack of fear against potential danger such as traffic – e.g. walking onto the street straight in front of an oncoming car [22, 26]. Very often as a result of all the above-mentioned behaviours difficulties in contact with other people appear, which stem from fear and lack of knowledge among healthy people as well as from misunderstanding the weird autistic behaviour [27].

We should honestly admit that at the beginning of the project both students and teachers involved in it had very superficial knowledge of the topic and rather stereotypical attitude towards autism. It was obvious that only deep analysis and profound observation would make it possible to understand the process – it is a necessary condition for professional designing for disabled people. Courtesy of the families, the management of the Foundation and the therapists we managed to analyse the course of therapy through personal experience during participation observations.

Where were the basic problems of the therapy of autistic people diagnosed?

By observing the process of therapy from the outside we should know that it must be analysed in a holistic way - both from the point of view of the child who is in therapy, his/her family as well as the needs of the therapist within the scope of assessing and controlling the long-term effects. The therapist and the child spend a lot of time together during classes and the result that we search for should fulfill the needs of both sides in terms of safety, comfort, easy use, aesthetics, practicality of the materials and solutions used. However, therapy does not end in the classroom at school. When the children come back home they should have access to objects which would support or at least strengthen the rehabilitation process [13, 15]. Thus, from the whole environment of therapy for autistic children particular areas were chosen for detailed analysis: the therapist's work, the child's needs and effort, selected products which support rehabilitation, and the role and possibilities to reinforce therapy by parents at home.

The therapists' side analysis

Polish therapists are undoubtedly very well-educated and prepared to do this difficult job. The main problems they encounter are usually rather mundane and well-known to every employee – not enough money for tools, too much bureaucracy, i.e. reports. During our interviews and conversations it was easily noticed that another crucial problem at work with autistic people can be the danger of occupational burnout [11]. The therapist's work is based on giving a lot of commands and repeating particular activities with the child many times. The classes are often spent trying to make eye contact with the patient, repeating sequences of exercises, which might seem monotonous. Such monotonous and long-lasting procedure can influence the therapist's self-esteem. Due to a long rehabilitation process and numerous difficulties, which occur in its course, therapists often barely notice the effects of their work, which leads to lack of satisfaction from work or even losing faith in one's skills [16]. The absence of visible progress and sometimes even withdrawal of the achieved skills through neglecting work at home make therapists have the impression they do the “Sisyphean labour” [25].

The patients' (children's) side analysis

During our visit in the seat of the Foundation the teams had an opportunity to see the process of therapy and interview therapists; nevertheless the children were only observed – often they do not even speak, thus, it would be hard to get any information from them. As a result, most of the conclusions are our subjective assessment corrected by the therapists. It is hard to imagine how a person with autism sees the world, especially as each case is individual and on a certain stage of therapy they cannot be reduced to a common denominator. It may take a lot of time to get to know the child's preferences and establishing contact with him/her. One of the aims of therapy is to get a patient accustomed to stimuli from the environment, which causes the patient's reluctance from the beginning. Huge hypersensitivity to some stimuli or total hyposensitivity to others automatically directs the therapy to balancing those stimuli. It is here that we encounter many difficulties, first of all caused by the fact, that an autistic person sees the surrounding world in a completely different way than a healthy person. In order to understand the problem best it is necessary to “impersonate” an autistic person. During the presentation conducted by the employees of Navicula Foundation the teams had the chance to “feel” how somebody suffering from autism sees the world when struggling with hyper – or hyposensitivity to selected stimuli. One of the more burdensome complications, which do not exist in the lives of healthy people, is the problem of selecting a chosen sound from the noise of the day and reinforcing it strongly. An attempt to focus the attention on something in the room is in such a situation a real challenge. This problem is often connected with the general hypersensitivity

of hearing and requires the children to wear headphones which filtrate the sounds from the surroundings. Another common problem observed with autistic children was also insensitivity to touch (hypotactility). It evokes the need to reinforce the stimulus of touch and is manifested by the love of strong hugs and sometimes leads to self-mutilation. Such people cannot adjust proper strength in contacts with other people – that is why when shaking hands with someone (if they do it at all) they can squeeze it really painfully without the intention to hurt. Favourite aids for such children are all kinds of objects with various texture or objects which allow them to practice the strength of touch and squeezing. Moreover, the sense of sight can also require reinforcing or muffling. It commonly happened that the children took shining objects in their hands and put them directly to their eyes in order to strengthen the sensation. Patients under Navicula's care are people from the age of [0-100 years], most often suffering from one or more other diseases apart from autism. Thus, we searched for solutions which would be universal and addressed to given age groups in order that they were adjusted to anthropometric measurements of the assumed users [18].

It is certain, that for autistic children – as well as for all the other children – the toys' (aids') colours, form, materials they are made of matter; we can notice individual preferences in this area. It is beyond doubt that therapy conducted during classes at school is not enough. Access to interesting devices in the seat of the Foundation only is insufficient for the effects of therapy to be preserved. It is necessary to continue the work at home as well for the benefit of the children. Unfortunately, in many cases the children get electronic devices to “play” with at home and they use them without their parents' control and without any special purpose – just to be focused on something [19].

It is important to notice the reluctance to change in autistic people [8, 20] – this could be the basis for the assumption that the toy should be designed in a way that makes it accessible for the child at home too and makes it a personal thing for the child to work and play with purposefully and with satisfaction [27].

Analysis of the didactic and rehabilitation aids that are used

A cycle of classes has the same established rhythm. A therapist works with one to three children and each task / command is stated clearly and many times, so that the child would be able to connect the task that s/he is doing with the word – command. The didactic and rehabilitation aids used in therapy are very often typical toys. Therapists also create objects which are useful for given patients. Often, toys which generate light or sound are used. Using such objects is usually a reward for a task well done. Such situation results in the child not focusing his/her attention on the task itself (which is the most important element of the therapy), but mentally searching for the reward. Other often used and useful things are objects with larger dimensions such as soft pillows to sit or lie on or weighted mats/blankets for covering a child. Therapists regularly use

schematic drawings which make it easier for the children to communicate their emotions, thoughts or needs. It is popular to work with objects with various texture – sometimes unpleasant when touched such as sticky tapes or very rough fabrics. In order to interest the patient in an object therapists use items that make sounds – the most popular being rattles filled with various materials such as little stones, seeds, beans, or sand. What is more, objects with different temperature are used – therapists freeze or warm up bottles with water for this. Some children like warmth and some prefer cold, it is hard to find ready made toys which offer such wide spectrum of temperature. Objects which vibrate when touched are also valuable aids for children and can support practising the strength of pressure or touch. Electronic items which make sounds or emit light give a lot of fun to the patients; however, their weak point is that the therapists cannot control the light or sounds much.

All the activities with sound are limited to playing already programmed sounds and the light can either be on, off or flashing. What is necessary is the gradual intensity or changing colours in case of lights and regulated level of sound to be adjusted to the child's needs or stage of development. All kinds of shining objects, or those which make sounds can require additional isolation from the surroundings, that is why some classes take place in darkened and closed (soundproof) classrooms.

During observations we noticed that due to lack of integrated objects which might be used in the whole process of therapy, a lot of various elements are introduced which cause unnecessary chaos in the child's surroundings. It is not hard to notice, that most of the toys used do not offer such wide spectrum of possibilities that would satisfy both sides in the long run. It would be advisable to combine several functions in one toy. The aids should give the therapists the possibility to adjust for varied needs of each child within the scope of compensating stimuli. And the child should be provided with an interesting object to play with and for therapy also outside the seat of the Foundation (at home or outdoors) if possible. It was also noticed that the object used for practice rarely had an integrated gratification system for a task well done. Usually, the reward comes later – the child receives something from the therapist. It would be valuable to construct the toys in a way which would make it possible to reward the child automatically after each cycle of tasks – possibly in the form of a stimulus chosen by the child. The quality and efficiency of therapy is also influenced by the possibility to increase/decrease the level of difficulty of tasks gradually [14]. A remote control of the process of an exercise would be useful – giving hints, guiding to work on correct reactions. Delicate suggestions how to perform a task correctly can give very good effects, especially in the therapy if autistic children. A subtle suggestion made with a favourite stimulus (with the lowest possible intensity) can draw a patient's attention. Such methods are always used by therapists in moderation in order not make the patient react to the stimulus only. A particularly big problem is rewarding the children who need to compensate for the sense of taste, because usually it is something sweet, sour, crunchy, hard or salty for eating or licking.

Storing such food products and giving them to the children as a reward is the therapists' responsibility and can cause problems – especially when the amount of calories must be controlled.

The parents' side analysis – the role of the home

Rehabilitation process for an autistic child is a continuous process – if it is conducted in an educational and rehabilitation institution only it might not bring the expected results.

Thus, a lot of responsibility lies on the parents' shoulders – they should and often do join the process of rehabilitation by doing tasks at home as well. Despite the fact that the knowledge about autism is deeper and there are many books about the disorder, the diagnosis is still a huge shock for the parents. Getting accustomed to the disease, getting to know it and learning how to help your child are necessary and take time and a lot of effort. That is why, parents also need interesting and in the same time financially and technologically accessible objects for supporting the rehabilitation to be used at home. Things for working at home should meet similar criteria to those used during therapy classes. A perfect solution would obviously be for a child to own a toy programmed especially for his/her needs.

It is necessary for the programming process to be simple and fast so that each parent could do it. Integrating the device with a smartphone or a computer and the possibility to control it with those things would be a good solution.

Parents, as those who are the most attached to their children and who spend time everyday with them, have the most difficulty in assessing or even noticing very slow progress. A monitoring system i.e. recording the process of therapy and the possibility to generate reports is as important for the therapists as it is for the families. It strengthens their belief in the efficiency of the rehabilitation and the validity of therapy [24].

The process of therapy at home is probably the weakest link in the whole integrated system of rehabilitation. This stems from the lack of properly designed devices which are widely accessible and easy to use as well as from the lack of time and energy to continue rehabilitation at home. However, because of the character of research and design works on this stage we did not focus on the role of home rehabilitation and it was not analysed in any way – the information about it comes from conversations with the therapists. Nevertheless, for an attentive observer like a designer, it is clear that the next thing to analyse, concentrate on and improve is the home and the closest surroundings of autistic people. The therapy of those who suffer from autism is a complicated, long-lasting process and it should be conducted in every area and in various environments – a proper programme of home therapy seems to be especially important.

In what way can the current situation be improved?

Guidelines for the system

A comprehensive outlook on the problem of therapy for autistic people leads to the conclusion that it is necessary to standardise the system of objects used in therapy in such a way that would make it possible to be used during classes at school as well as at home with the same effectiveness. The items should have an easy system of programming tasks, an integrated reward system but they should also signal correct solutions. The designed objects cannot only be devices – they need to be therapy tools - but first of all they must be nice toys, attractive for a child. Providing safety of use and support in forming basic social habits to make it easier to function in the world are also indispensable. In accordance with the suggestions made by the therapists and in connection with the fact that the children's progress is spread over time, the solutions we search for ought to offer the possibility to adjust the tasks to the needs and skills of a patient freely, but also record the results according to the selected parameters. It is crucial for the toys to combine a couple of stimulants such as light, sound, movement (vibrations) to be chosen in harmony with the child's needs and preferences. It is possible to find solutions which engage state-of-the-art technology and materials – very prospective – but most often they will be expensive and rather inaccessible for the interested sector. Thus, we should seek such solutions which will be innovative, but not costly. Using contemporary technologies and common materials will lead to cost optimisation and as a result will widen the group of potential receivers. It is reasonable to organise interdisciplinary teams composed of designers and engineers who specialise in programming and making robots. Such complex and multilateral approach can lead to creating optimal solutions which combine modern technologies, durable materials interesting and premeditated use process and all that packed into a well-designed pretty form [23].

Proposed solution – selected objects designed by the interdisciplinary teams

After a visit to Navicula Foundation, which overflowed with experiences and information, concept works started which aimed at selecting and solving the most crucial problems. This way integrated objects which fulfil the needs of children and therapists were designed and created by interdisciplinary teams from the Strzemiński Academy of Arts (ASP) and Lodz University of Technology (PŁ).

Most of the observed problems can be solved by using the devices designed by the teams from ASP and PŁ. Unfortunately, after deeper analysis it turned out that many of the objects could only be used for a few patients and could not be treated as universal or multipurpose enough. Our partners from Navicula Foundation clearly expected objects which could be used in therapy with more

patients. As a result, the objects needed to be adjusted for controlled stimulation for the chosen sense. The most difficult problem was the compensation of the sense of taste, as most of the solutions would be some kind of food distributors which would cause sanitary problems or maybe even health problems for the children if they played with the devices unsupervised. Thus, we focused on safe solutions which allow fast prototyping for preliminary tests.

As children with autism are often interested in robots, the idea of the project was to create robots toy for teaching [2, 3, 7]. Most of the designs concentrate on using the stimulation of the sense of touch and sight. The designs developed in the direction of objects for supporting relaxation and toys for education and rehabilitation. Students put a lot of stress on the issue of rewarding and providing children with well-being. The proposals which were made might be used freely in therapy of children of a large age interval.

Sleeve Robot

One of the first objects designed as part of the co-operation of ASP and PL is the Sleeve (Fig. 1), i.e. a device which supports the stimulation of arms within the scope of varied textures, changeable temperature, vibration and delicate light stimulation for the eyes.

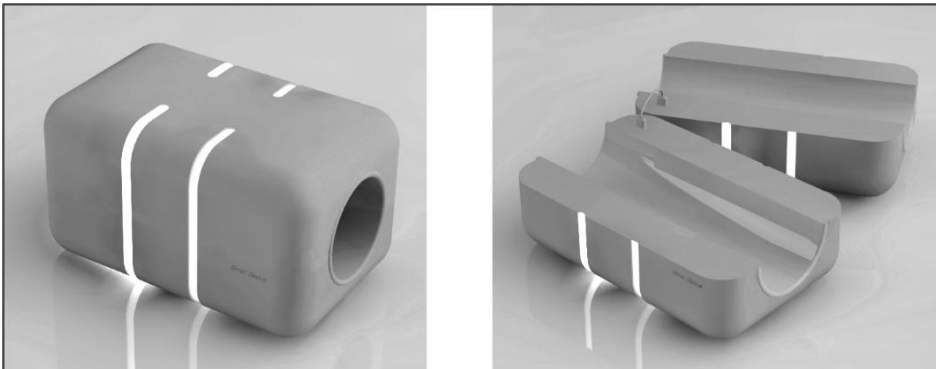


Fig. 1. The Sleeve Robot
Source: students' works [5].

The Sleeve is built from two identical halves which are in the shape of an arm inside and are equipped with changeable inserts with different textures, hardness and colours. It is possible to stimulate both arms in the same time on the separated halves or creating a fuller experience in a tunnel created when the halves are put together. The aim of the activity is to put one's arm inside the tunnel and experience various textures – the reward is warming up or cooling down the arm and vibrations. When the task is performed correctly a LED light tape on the case of the Sleeve turns on – which is also a form of encouragement.

The item is built on a construction made from plywood and covered with a durable skin-like fabric filled with sponge in order to ensure better safety and comfort of use. Its construction makes it possible to open the casing and repair or service the electronic elements inside. Despite its large size – $35 \times 35 \times 50$ cm – the Sleeve is relatively light and thanks to magnets a child can put it together and dismantle it on his/her own, which can be an additional attraction. The colours are soft but varied and it is possible to change them with interchangeable elements. The Sleeve can be used during therapy at school as well as at home while playing with the parents.

Box Robot

Another object created and tested in the seat of Navicula Foundation is a sensory cube (Fig. 2). The object has five function walls which help in therapy by stimulating touch, sight and hearing. The Box can support the learning of correct touch (e.g. stroking with the right pressure).



Fig. 2. Box Robot
Source: students' works [4].

The cube should stand on legs and then, thanks to using simple mechanisms, it can move up 2 cm – such movement depends on the therapist and is controlled from a smartphone or can constitute a reward for the child for touching a wall correctly.

The remaining 4 walls are used for attaching elements with various textures with the use of Velcro or a magnetic mat. The fifth function wall is covered by opaque surface of 20×20 cm which hides LED diodes. By programming it correctly it is possible to light up different sequences of colours or icons of smile or sadness. Such action can be a reward for a task well done.

The Box Robot is average-sized – $30 \times 30 \times 30$ cm, is relatively light, which makes it possible for the child to carry it freely. In addition, in the sides of two walls holes were cut out to hold it easily. An inflexible construction made from

ABS and plywood was covered with distance fabric which creates a protective layer for the inside construction.

Outside, a case made from skaden – a polyester fabric, which is easy to keep clean, with a zip that makes it possible to get inside in order to repair and service the electronic elements. The case is neutral in colour (light beige) in order not to compete with multicoloured LED diodes and almost any colour of the interchangeable textures and fabrics. Small size and multipurpose use make the Box Robot universal – it can be used in therapy at home and at school.

Pillow Robot

The objects that appear next are on the stage of initial prototypes and after firsts tests in the seat of the Foundation.

The interactive pillow (Fig. 3) which supports the children's therapy can become a significant element in an educational and therapy classroom's equipment. It can be a place of well-earned rest and relaxation while working or learning, or it can be a reward after a well-done task. The pillow is quite big, but its size is justified by the fact that it is to be used in therapy classrooms. The first thing that the team noticed was that children quite often sit on the floor during therapy, that is why the team decided to design a pillow for sitting on with surprises. It is filled with pellets and mechanisms which enable controlling the vibrations and lightning. The covering fabric has various kind of texture – soft, rough, slippery – interchangeable to correspond with the child's preferences.



Fig. 3. Pillow Robot
Source: students' works [1].

Optionally, it is possible to use different temperatures – the topic is currently being analysed. Touch sensors that are placed on the Pillow turn on light effects, and the mobile elements of the filling that move the pellets provide a massage – also possible with the use of vibrations. During the first tests it was positively approved by the users and the therapists suggested that we should add a weighted blanket as extra stimulation – valued by many children a lot. The Pillow is blue as part of promoting this colour as the colour of autism.

Sensory Mat Robot

The mat (Fig. 4) includes five two-sided elements which can be connected with one another in different configurations. The object is enriched in a central soft robot for sensory therapy. The elements of the mat might be joined together creating a path or a circle around the robot. All the elements of the mat are soft, that is why a child can lay down on them. Each element has two sides with different intended use – one side provides stimuli thanks to various textures, and the other is used for attaching chosen toys with Velcro.

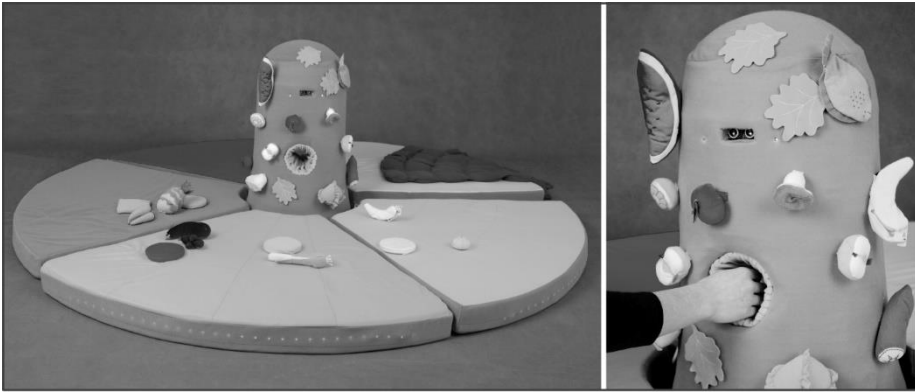


Fig. 4. Sensory Mat Robot
Source: students' works [12].

The whole set includes a robot shaped like a barrel and five elements (arches) which create a circle. We have the first element covered with fur, the second covered with dimpled sheeting, the third with acoustic foam, the next one with satin and the fifth is a weighted blanket with vibrations. The other sides of the elements are smooth, colourful surfaces dedicated to games and tasks which are adjusted by the therapist to the child's stage of development. They make it possible to attach any object with Velcro to the mats. Additional element of the set is an illuminated path where each arch can be placed. Every module of the mat can be rotated in the path freely in order to uncover the side with the texture or the one with the game – in any configuration. Another option of arranging the mats is joining them with poppers to create a circle with the central place for the robot. The robot can control the lights of the path and make sounds which support educational games. It can repeat various sounds and voices. Inside the robot, there is a pumping sleeve where a child can put his/her arm and as a reward the tunnel will tighten as in a manometer. The button which starts the sleeve is on the robot. The robot can also be controlled from outside via a mobile device. The object is charged with a battery charger.

Hextep Robot

Hextep (Fig. 5) is an interactive game which supports therapy of children with ASD. It is a set of three or more flat hexagonal modules with LED lights displays. Each module has the possibility to display letters and numbers. In a more advanced version it can also display shapes, colours and selected symbols. Each of the elements shows a random letter or a number during one “round”. The process of the game can be adjusted to the age and weight of the child who is using it. You can play on the floor (a child can stand on each of the modules), on a table or the modules can be mounted on the wall.

The therapist chooses one of the symbols and asks the child to point to it or stand on it. If the child has a problem, the therapist can give the patient a clue with a remote control in the form of a sound or by lighting up the element. If the child chooses the correct module the therapist can also turn on the reward – a flashing image and/or vibrations of the selected module – depending on the child's preferences.

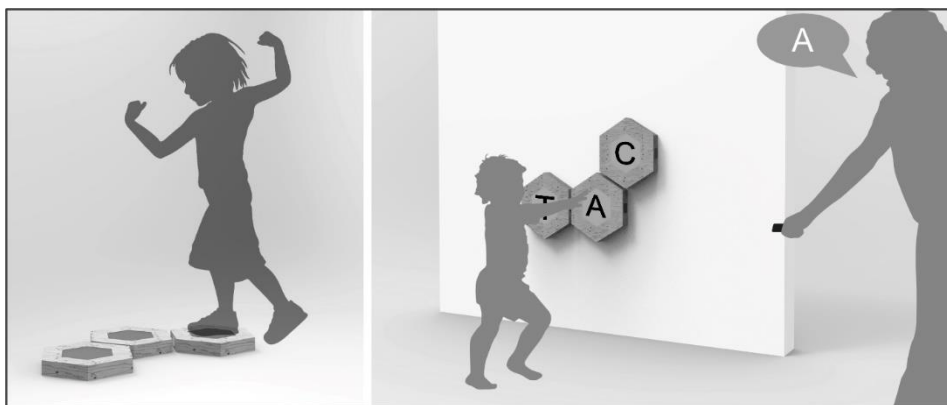


Fig. 5. Hextep Robot
Source: students' works [10].

The therapist controls the game with a remote control. The game not only teaches recognising letters, but also (which is extremely important for autistic children) requires focusing on individual objects in space. The elements are made of plywood with an internal strengthening of the construction to make it safe for children of around 20 kg to stand on it. Its size enables standing on it, putting it on a table or mounting it onto a wall. A more comfortable version can be covered with fabric and the top of it can be upholstered with skaden, which is easy to keep clean, with a zip to make it possible to open it when you need to service the electronic elements. The toy has a universal form and wide possibilities and thus it can be used by parents to continue therapy at home.

Panda Robot

As children with autism are often interested in robots, the idea of the project was to create a robot toy for teaching touch (Fig. 6). Due to a lower level of complexity of interaction and fewer stimuli provided, it is easier for the children to come into contact with the robot than it is with other people. The basic task here is to teach the child proper interpersonal interactions within the scope of touch mainly. In addition, the form of the robot can also familiarise children with a face.

The basic rule here is quite simple – the child’s task is to stroke the robot. If s/he does it with the proper gentleness/pressure, the robot gets happy – purrs/lights up/vibrates – and in this way rewards the child by stimulating the selected senses.

When the child squeezes the robot too hard, hits it or throws it on the floor, the robot turns off the functions which are attractive for the child – stops shining or makes an unpleasant sound or even turns off completely for a defined period of time. Another form of therapy can be playing hide and seek. The therapist hides the robot, the robot makes sounds and helps the child in searching. When the robot is found the child is rewarded with stimuli which are attractive for him/her.

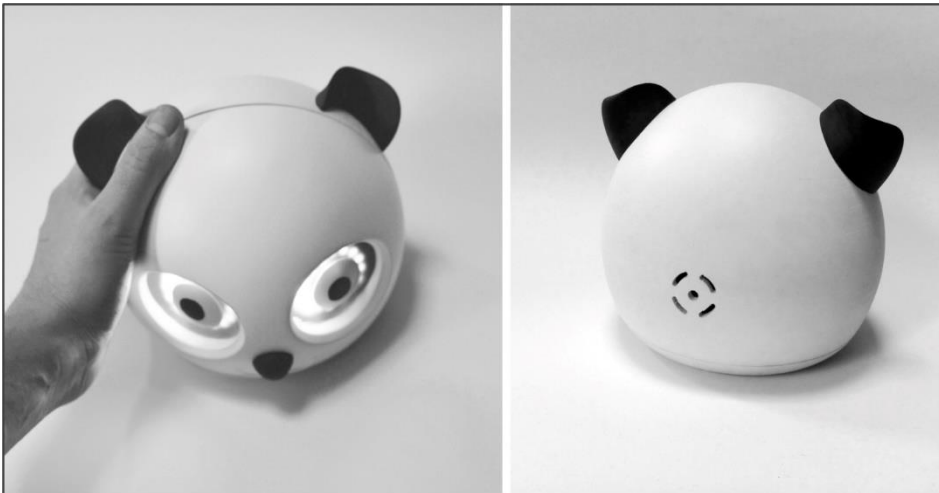


Fig. 6. Panda Robot
Source: students' works [17].

The robot’s functions can be programmed in compliance with the patient’s needs. The possibility to adjust the kind of sound and the level of vibrations is crucial in the effectiveness of therapy. An additional element which allows adapting the robot to the needs and preferences of each child is changing its outer cover. The therapist is responsible for “dressing” the robot in proper clothes, the activity is simple and quick – there is a zip at the back of the cover.

The basis for the design of the prototype is a solid figure printed by a 3D printer with the use of plastic which enables free access to its insides where the electronic components are placed (wi-fi module, micro controller, sound card, battery, vibrating engine). On the outside of the sphere there are pressure sensors which measure the sensitivity of the robot's cover, which responds to touch. In the wholes in the head of the robot, there is space for the “eyes” in which LED diodes are placed (as in other elements of the robot's cover). The eyes are made of semitransparent material, attached to the inside sphere (which constitutes the robot's base). In another version of the project, the robot can emit light with all its surface. An additional attraction is the possibility to make several covers – clothes, which would make it possible to personalise the robot for a given child (with various colours of textures). Such a Panda robot can become a permanent companion, at home as well.

Summary

The solutions presented above seem to be a valuable additions and an extension to the market offer within the scope of objects/toys supporting therapy of children suffering from ASD. The solutions use modern technologies and commonly used materials, are simple in construction and easy to service. First of all however, they attract attention with their appearance and a precisely designed use process. They are safe and interesting for the user. Some of them might be promoted as toys to support therapy at home under the parents' or siblings' control. It is necessary to conduct a number of tests and obtain therapists' opinions; nevertheless, we are at the beginning of our way and with every object we know more about the needs of the children and our possibilities in the field of helping them with the use of robots. It seems that slowly – in accordance with the motto of the social campaign “Don't be green when it comes to autism – in April – be blue” – we get more and more blue in this topic all year long.

References

- [1] **Abramczyk, K., Furmańczyk, J., Samek, K., Wańczyk, A.:** Student's work, Academy of Fine Arts and Lodz University of Technology, academic year 2015/2016.
- [2] **Arent, K., Kabala, M., Wnuk, M.:** Programowanie i konstrukcja kulistego robota społecznego wspomagającego terapie dzieci autystycznych, Ph.D. dissertation, Politechnika Wroclawska, 2005.
- [3] **Barakova, E.I., Gillesen, J., Huskens, B., Lourens, T.:** End-user programming architecture facilitates the uptake of robots in social therapies, *Robotics and Autonomous Systems*, Vol. 61, No. 7, 2013, 704-713.
- [4] **Bartczak, M., Belkner, P., Kowalik, A., Rogalska, O., Surma, Sz.:** Student's work, Academy of Fine Arts and Lodz University of Technology, academic year 2015/2016.

- [5] **Barzdo, K., Belkner, P., Kulik, K., Jarosiński, M., Matuszak, Ł., Polański, M., Rajska, D., Surma, Sz.:** Student's work, Academy of Fine Arts and Lodz University of Technology, academic year 2014/2015.
- [6] **Branowski, B., Zablocki, M.:** Kreacja i kontaminacja zasad projektowania i zasad konstrukcji w projektowaniu dla osób niepełnosprawnych, [in:] Jabłoński J. (ed.): *Ergonomia produktu. Ergonomiczne zasady projektowania produktów.* Wydawnictwo Politechniki Poznańskiej, Poznań 2006, 73-106.
- [7] **Cabibihan, J.J., Javed, H., Ang, M., Aljunied, S.M.:** Why robots? a survey on the roles and benefits of social robots in the therapy of children with autism, *International Journal of Social Robotics*, Vol. 5, No. 4, 2013, 593-618.
- [8] **Cashin, A., Barker, P.:** The triad of impairment in autism revisited. *J Child Adolesc Psychiatr Nurs* 22(4), 2009, 189-193.
- [9] **Frejlich, Cz.:** Ergonomia i wzornictwo. [in:] Jabłoński J. (ed.): *Ergonomia produktu. Ergonomiczne zasady projektowania produktów.* Wydawnictwo Politechniki Poznańskiej, Poznań 2006, 177-198.
- [10] **Janiak, K., Kopania, D., Łuczak, P., Smyczyński, P.:** Student's work, Academy of Fine Arts and Lodz University of Technology, academic year 2016/2017.
- [11] **Jennett, H.K., Harris, S.L., Mesibov, G.B.:** Commitment to philosophy, teacher efficacy, and burnout among teachers of children with autism, *J. Autism Dev. Disord.*, Vol. 33, No. 6, 2003, 583-593.
- [12] **Koziol, J., Pieczara, I.:** Student's work, academic year 2016/2017.
- [13] **Lecewicz-Bartoszewska, J.:** Wzornicze projektowanie ergonomiczne pomocy rehabilitacyjnych dla dzieci z dysfunkcją ruchu. *Przegląd Pediatryczny. Suplement 1*, Wyd. Cornetis, Wrocław 2005.
- [14] **Lecewicz-Bartoszewska, J., Miarka, A.:** Zabawa i zabawka jako integrujące nośniki rehabilitacji społecznej, [in:] Kabsch A. (ed.), *Zeszyty Promocji Rehabilitacji*, Zeszyt 5. Problemy rehabilitacji kompleksowej w zaburzeniach rozwojowych, Ośrodek Wydawnictw Naukowych, Poznań 2009, 87-101.
- [15] **Lecewicz-Bartoszewska, J., Miarka, A., Bittner-Czapińska, E.:** Zabawki jako nośniki funkcji rehabilitacyjnych, [in:] Lewandowski J., Lecewicz-Bartoszewska J. (eds.) *Ergonomia Niepełnosprawnych w wieku nanotechnologii i w ochronie zdrowia* Wydawnictwo Politechniki Łódzkiej, Monografie, Łódź 2006, 179-190.
- [16] **Leka, S., Jain, A.:** Health impact of psychosocial hazards at work: an overview. *World Health Organization*, 2010, 66-67.
- [17] **Madej, A., Majewski, K., Perenc, I., Pernak, W.:** Student's work, Academy of Fine Arts and Lodz University of Technology, academic year 2016/2017.
- [18] **Miarka, A.:** Projekty zabawek dydaktyczno-rehabilitacyjnych dla dzieci niepełnosprawnych intelektualnie, [in:] Lecewicz-Bartoszewska J., Niziołek K. (eds.) *Ergonomia Niepełnosprawnych współczesne i przyszłe kierunki rozwoju.* Wydawnictwo Politechniki Łódzkiej, Łódź 2011, 127.
- [19] **Miarka, A., Lecewicz-Bartoszewska, J.:** Designs and studies of application qualities of rehabilitation mats, [in:] Wiśniewski Z., Lecewicz-Bartoszewska J. (eds.) *Ergonomics for the disabled – life activation, rehabilitation ergonomics aspects*, Publisher Lodz University of Technology, Lodz, 2013, 75-91.
- [20] **Volkmar, F.R., Reichow, B., McPartland, J.:** Classification of autism and related conditions: progress, challenges, and opportunities, *Dialogues Clin Neurosci.* 14(3), 2012, 229-237.
- [21] **Wall, K.:** *Autism and early years practice.* Sage, Thousand Oaks, 2009.

- [22] **Wing, L.:** Autistic spectrum: a guide for parents and professionals, Constable, London, 1996.
- [23] **Zubrycki, I., Granosik, G.:** Technology and art – solving interdisciplinary problems, 6th Int. Conf. on Robotics in Education RiE 2015 HESSO.HEIG-VD Yverdon-les-Bains, 2015.
- [24] **Zubrycki, I., Granosik, G.:** Understanding Therapists' Needs and Attitudes Towards Robotic Support. The Roboterapia Project, International Journal of Social Robotics Volume 8, (4), 2016, 553-563.
- [25] **Zubrycki, I., Kolesiński, M., Granosik, G.:** A participatory design for enhancing the work environment of therapists of disabled children, 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), New York, USA, 2016, 781-786.
- [26] www.autismaction.org/about-autism/what-is-autism/signs-of-autism/ - accessed on 03.10.2017.
- [27] www.navicula.pl.

UNIVERSAL DESIGN WITH ICT SOLUTIONS

ERGONOMIC ANALYSIS AND THE TRACKING SYSTEMS

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Abstract: The article deals with the possibility of implementing the tracking systems in a digital factory and the subsequent by implementing ergonomic analysis in this environment. The emphasis is on research results in the area of connection of simulation software on the inertial and optical Motion Capture systems. The importance of these analyses is to estimate as accurately as possible the effects on human health due to the design of work systems at the design stage. This article deals with the results of laboratory verification and the results of implementation outputs.

Keywords: Tecnomatix Jack, Microsoft Kinect, Tracking system, ErgoPAK.

Introduction

Along with the development of digitisation and the concept of a digital factory, ergonomics is gradually becoming a part of complex corporate systems, which greatly facilitates ergonomics in designing and optimising production, assembly and support processes. The development of ergonomic assessment and design of workplaces is aimed at the active use of wearable sensors, the use of virtual and augmented reality, motion capture systems, modelling and simulation of workplaces and work activities, and the collection of real-time data.

These technologies do not interrupt manufacturing processes, they do not create downtime, and can give us an immediate initial response in terms of proposal layout, so the design can be improved without any cost increases. The assessment of the collected data can be subsequently used in assessing ergonomics of workplaces, designing new workplaces, assessing labor productivity and many other areas.

Workplace design using Tecnomatix Jack

Tecnomatix software is a product package developed by the company Siemens PLM Software. Tecnomatix includes software solutions from different production areas that are mutually connected. This software helps us to design manufacturing and assembly process quickly and precisely. Thanks to the simulation and optimisation in a development phase we can ensure high quality product, without need to additionally apply for financial and time-consuming changes [5].

Tecnomatix Jack is one of several modules. It was developed at the University of Pennsylvania. It is focused on ergonomics analysis and a correct working environment proposal. In this software, you can create a workplace from the individual components. Simple 3D models can be created directly in Jack and complex 3D models can be imported in several formats. The best compatibility is achieved when .jt format is used. 3D models in .jt format can be created in other modules of Tecnomatix as NX or FactoryCAD. Disadvantage is that it is impossible to copy 3D models; so, if we want to use the same 3D model several times we have to import it more times or we can use special plug in which is made for it, but we have to download it from the community page. The fact that TX Jack is open source software is great advantage because if you need some functionality very often you can code it for yourself [12]. In software Jack we prepare a workplace at required dimensions and then we put in an anthropometric and biomechanical accurate mannequin of a man with natural human motions and joint range. Ranges and dimensions were taken from NASA studies. The mannequin consists of 71 segments and 69 joints, some of them have several degrees of freedom. The mannequin figure has 135 degrees of freedom. Dimensions of the mannequin body can be selected in an extensive library of exact anthropometric dimensions from different areas of the world.

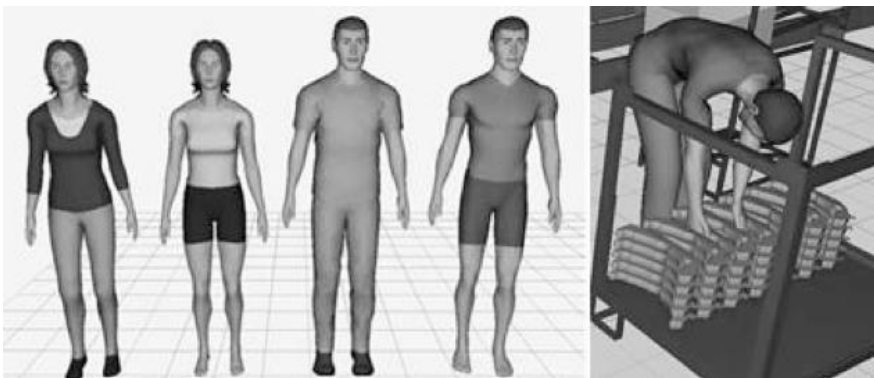


Fig. 1. Mannequins with plastic skin
Source: own study.

Software provides several options for adjusting working postures. It is possible to use library with 30 basic postures and 27 basic grips. Alternatively, it is possible to modify these basic postures in several ways. The program enables to adjust the mannequin posture to last fingertip. When the posture is set, it is possible to evaluate the visual field, view cone for one or both eyes or evaluate reach-zones of the operator based on several rules [4].

Software also include important ergonomic analyses as OWAS, RULA, NIOSH, Low Back Analysis, Static Strength Prediction or MTM. These analyses can be found in Task Analysis Toolkit. For example, the RULA assessment tool considers biomechanical and postural load requirements of work tasks on the neck, trunk and upper extremities. It is designed for quick assessment of a working posture and identifies the risks of MSD. An OWAS-based analysis shows us the four-place code indicating the back position, hands position, feet position and load level for the selected working posture and shows result of corrective recommendations [11].

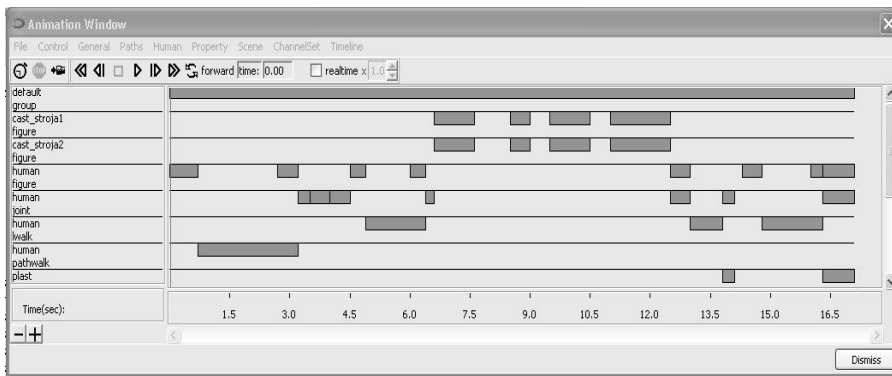


Fig. 2. Sequences of movements in animation mode
Source: own study.

Occupant Packaging Toolkit module is specifically designed for automotive industry. It includes further analysis as a detailed assessment of the visual area, colour recognition, visibility of selected objects.

Software can also create animations of movements to evaluate the load of operator continuously in motion. There are two ways how to make movements manually. We can use animation and simulation mode. These ways of movement's creation are very time consuming because we have to create every simple movement through joining static postures.

Tracking systems

Another possibility how to move a figure in the virtual environment is to use tracking systems. These systems deal with movements recording. There are several categories of these technologies. The first category is tracking of one

point. We track only a position of the beholder. The movement is saved in three axes x , y , z . The second alternative is to track the user's whole body. This process is called body tracking. We can track the whole body with scene identification systems (for example, Microsoft Kinect) or by adding several markers on the user's body. This method is usually done via a special suit called Motion Capture with precise disposition of markers. The final alternatives are special tracking systems focused on special areas of tracking as the eye or face tracking [1, 8, 9].

In the next part, we will introduce two of these technologies Motion Capture and Microsoft Kinect. It dealt during the research their interconnection with software Tecnomatix Jack.

Motion Capture

Using the Motion capture system, it can record the movements of the operator very accurately. This special suit can work on few technologies, for example, on the optical principle. The operator has a suit with optical sensors. He is tracked with more than two special cameras detecting his position at the workplace.

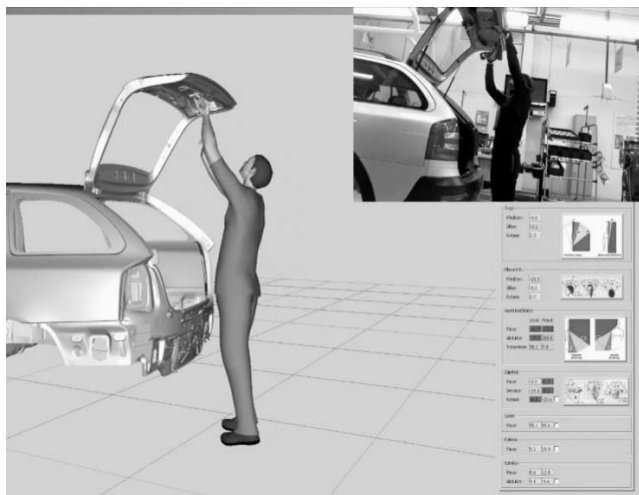


Fig. 3. Motion Capture Animazoo IGS 180

Source: own study.

Another tracking technology is provided by the company Animazoo. Motion Capture from this company was used in connection with TX Jack for the first time in Škoda Auto Mladá Boleslav in the Czech Republic. For connection with software Jack it was necessary to use special software IGS Jack. It is part of the Motion Capture package. This Suit works on detecting position on sensors consisting of a gyroscope and accelerometer. A gyroscope is a device for

measuring or maintaining orientation, based on the principles of angular momentum. Mechanically, a gyroscope is a spinning wheel or disk in which the axle is free to assume any orientation. At present, it can be based also on electronic or fibre optic principles [14]. An accelerometer is a device that measured proper acceleration. Motion Capture IGS 180 has 18 movement tracking sensors.

In the Fig. 3 is the digital human model of the worker at the assembly 5th door of a car. On the right upper part of the picture is a real worker dressed in IGS 180. On the right lower side of the picture is the application for evaluation of human postures based on Czech legislation. It is one of more outputs of common research with Skoda Auto.

Microsoft Kinect

It is a device used for body tracking. It was originally developed for a game console Xbox 360. But some people started thinking about its industrial usage too. The first Kinect can recognise movements from 1.2 m. In the year 2012, Microsoft introduced Kinect for Windows. This device is designed for operation system Windows and its versions Windows 7, Windows 8 or Windows 10 and can recognise movements from 0.5 m. Microsoft also released Kinect's SDK (Software development Kit). It allows developers to write their own applications in programming languages Visual Basic or C++.

Kinect for Windows used during the research consists of a VGA camera that captures three basic colour scenes (it enables human recognition ability), depth sensor that enables 3D space recording, microphone that enables also voice commanding in applications and from tilt motor in the sensor that enables the tilt the field of view.

Colour VGA video camera – this video camera aids in facial recognition and other detection features by detecting three colour components: red, green and blue. Microsoft calls this an “RGB camera” referring to the colour components it detects.

1. Depth sensor – an infrared projector and a monochrome CMOS (complimentary metal-oxide semiconductor) sensor work together to “see” the room in 3-D regardless of the lighting conditions.
2. Multi-array microphone – this is an array of four microphones that can isolate the voices of the users from the noise in the room. This allows the user to be away from the microphone and still use voice commands.
3. A further look at the technical specifications for Kinect reveal that both the video and depth sensor cameras have a 640×480 -pixel resolution and run at 30 FPS (frames per second).

The specifications also suggest that sensor allows about 1.8 meters of visible space between you and the Kinect sensor, but its variation depends on where is the sensor placed. If the height above the floor is not optimal (0.6-1.8 metres), nothing appears [7].

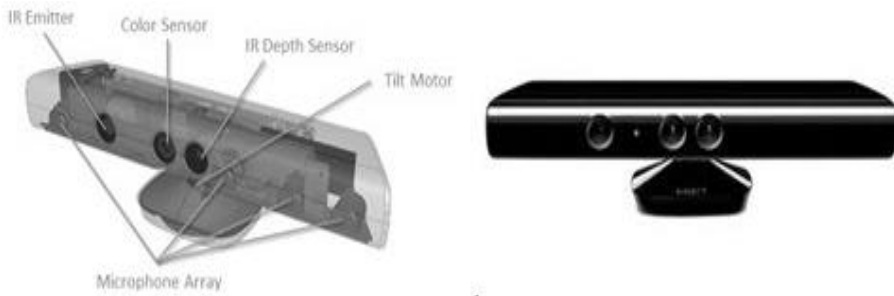


Fig. 4. Kinect for Windows
Source: [16].

It was needed a special Plug in to use Kinect with Tecnomatix Jack during the research. This Kinect Plug in has two different modes. An exploration mode is focused on the developing of surrounding. The operator selects one human figure and fly through a created scene. For orientation, using the hands. The right hand, enables movements to the sides and to the front. The left hand, enables up and down movements. A posture mode is focused on a quick posture creation. Kinect records the movements of the operator and they are carried to the virtual figure in Jack.

The current version can recognise well only a movement when human is oriented directly on Kinect and for posture creation not all sixty-nine joints are used, but only twenty of them. With this device, we cannot track fingers at present. It is also impossible to record movements created via this device; you can just save static postures.

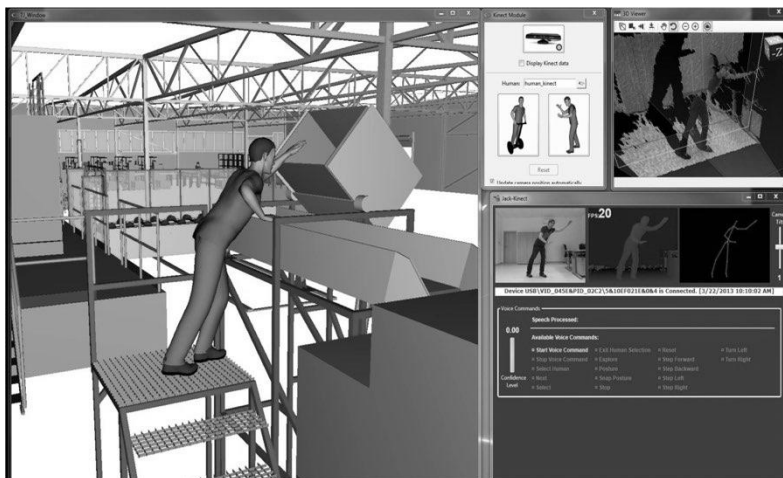


Fig. 5. Posture creation using MS Kinect
Source: own study.

The use of these tracking technologies in Tecnomatix Jack can significantly shorten time of animation creation and of dynamic loading appraisal. They can save hours of time when evaluating longer movements, because you do not have to create movement manually; you create it thanks to the saving your own movements. These technologies do not work always properly yet, but they are rapidly developing. We believe that in the future this type of the operator loading appraisal will be common and often used.

Measurement of loading using ergopak

Assembly is a collection of activities aimed at creating a functional unit (machine, equipment, etc.) by means of joining various components. Usually it is the last stage of production, followed by functional testing and running in. It has decisive impact not only on quality and reliability of products, but also on productivity and efficiency of the whole assembly and production system. The assembly of difficult products is still manual work even in automotive or mechanical industry. Therefore, it is necessary to ensure suitable working conditions during designing assembly workstations. When the operator manipulates a hand tool or some other object (e.g. drilling machine) in an incorrect way many times per day, it can cause serious health problems. That is the reason why it has to know how to measure loading [6, 2].

During a solving a real project, there is no problem to detect real weight of components or work pieces, but there is problem how to detect real load on the worker while pushing or pulling something [10].

There are several possibilities how to measure this loading. One of them is ErgoPAK. It is a tool kit for collecting and analysing data under real job conditions. It can measure force, velocity and also angle of joints during a work activity. It has few sensors that can measure push or pull. Each sensor is calibrated independently. Its wireless hub has eight ports so you can use more sensors at the same time. For collecting and processing data you have to install special ErgoPAK data acquisition software. But it is very user friendly [3, 15].

ErgoPAK tool kit includes following 8 sensors:

- 1st Handle sensor for measuring push or pull of both hands.
- 2nd Handle sensor for measuring push or pull of one hand.
- 3rd One finger sensor for push measuring.
- 4th Two fingers sensor for push measuring.
- 5th “Mushroom” sensor for push measuring of the whole hand.
- 6th Gyroscopes for angle measuring.
- 7th Accelerometers for acceleration measuring.
- 8th Special glove with four push sensors measuring each finger independently.

This device is able to capture one hundred elevations per second. It means that we get about one thousand values in ten seconds. Push values are captured in positive numbers and pull values are captured in negative numbers.

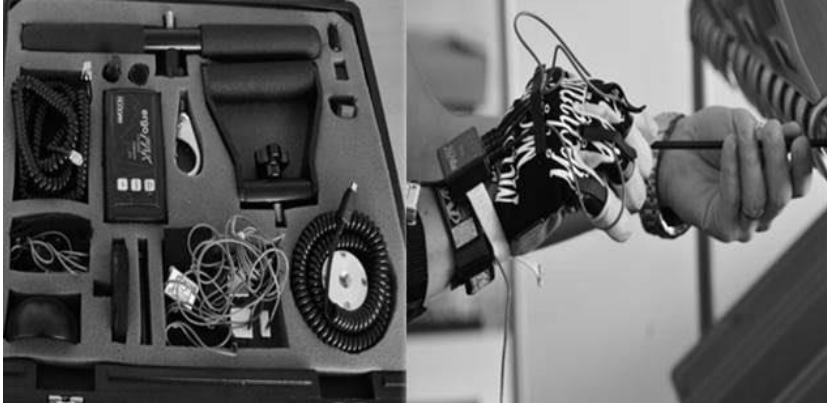


Fig. 6. ErgoPAK tool kit
Source: own study.

In Figure 6 you can see a sample of the pushcart pulled with two hand handles. In Figure 7 it can see push forces at four fingers and pull force needed for movement of the pushcart.

It is very important to know the right loading values especially in assembly processes where the same movements are repeated very often. Because when they have some harmful influences they can cause serious health problems. The research dealt with the possibility how to measure push and pull forces in working and assembly processes using ErgoPAK tool kit and how to use these values in loading appraisal. Loading appraisal can be also done in many other ways [7, 13].

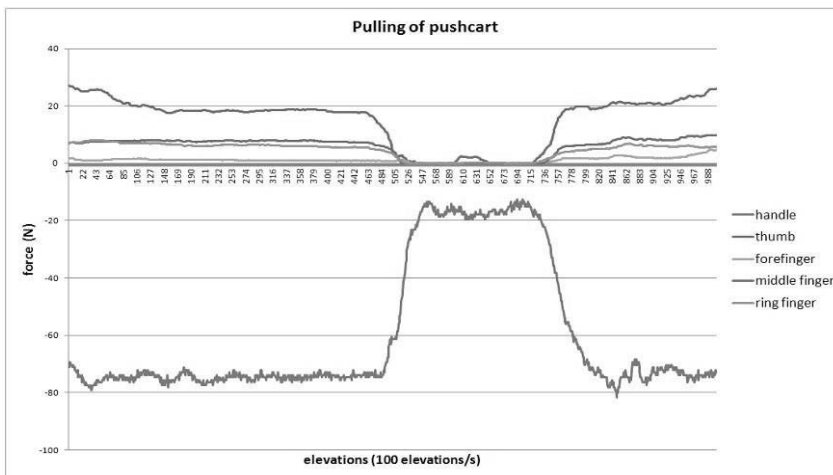


Fig. 7. Pulling of pushcart – measured values
Source: own study.

Conclusion

In the time of rapid changes in demand it is necessary to flexibly react to customer requirements. Because of that it is necessary to rebuilt and change existing working and assembly workstations. Modern information technologies and software solutions give a range of possibilities to try new ways how to design or evaluate a workstation. We introduced one possible software solution Tecnomatix Jack and its features.

These technologies can be also used as an effective tool for designing workplaces for disabled workers and to simplify the process of integration into work process. An example of this use is the collaboration of the Ergonomic laboratory of the Department of Industrial Engineering at the University of Žilina and the Faculty of Architecture of the Slovak Technical University in the development of the prototype axial crutch. During the research was used ErgoPAK system to measure the specific pressure on the underarm when using classical crutches and these outputs was used to design and testing the prototype of the new crutches.

These technologies are not without defects or disadvantages, but they are constantly developing. The assumption is that these technologies will become more and more common and widely used. They will be very helpful because already the current versions shorten time of designing and significantly reduce costs.

References

- [1] **Bubeník, P., Horák, F.:** Proactive approach to manufacturing planning, [in:] Quality Innovation Prosperity, Vol. 18, No. 1, 2014, 23-32.
- [2] **Canneta, L., Redaelli, C., Flores, M.:** Digital Factory for Human-orientated Production Systems. Springer. 2011.
- [3] **Furmann, F., Furmannová, B., Wićcek, D.:** Interactive Design of Reconfigurable Logistics Systems, [in:] Procedia Engineering, Vol. 192, 2017, 207-212.
- [4] **Gregor, M., Haluška, M., Fusko, M., Grznár, P.:** Model of intelligent maintenance systems, [in:] Annals of DAAAM Proceedings of the 26-th DAAAM International symposium on intelligent manufacturing and automation. Vienna: DAAAM International Vienna, 2016, 1097-1101.
- [5] **Gregor, M., Herčko, J. Grznár, P.:** The factory of the future production system research, [in:] ICAC 2015 Proceedings of the 21-st International conference on automation and computing. Glasgow, UK, IEEE, September 11-12, 2015, 1.
- [6] **Hovanec, M., Sinay, J., Pačaiová, H.:** Application of Proactive Ergonomics Utilizing Digital Plant Methods Based on Augmented Reality as a Tool Improving Prevention for Employees, [in:] International Symposium on Occupational Safety and Hygiene: 13-14.2.2014: Guimares, Portugal, Guimares: SPOSHO, 2014, 182-185.
- [7] http://ac.els-cdn.com/S1877705817325821/1-s2.0-S1877705817325821-main.pdf?_tid=e1251f72-6c7b-11e7-bb70-00000aach35d

- [8] <http://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-article-BSL9-0051-0052>
- [9] **Kall, F., Bartánusová, M.:** Using Tracking Systems for Ergonomic Analysis, [in:] Transcom 2013, Section 6: Machines and Equipment Applied Mechanics, 2013, 157-160.
- [10] **Kall, F.:** Appraisal of workplaces using modern ergonomics solutions, [in:] Advanced Industrial Engineering, Wydawnictwo Fundacji Centrum Nowych Technologii, Bielsko-Biała, 2013, 81-92.
- [11] **Krajčovič, M., Furmann, R.:** Modern approach of 3D layout design, [in:] Transcom 2011: 9-th European conference of young research and scientific workers, EDIS Žilina, 2011, 43-46.
- [12] **Matuszek J., Więcek D.:** Współczesne metody i techniki projektowania procesów przygotowania produkcji. Organizacja i zarządzanie: Zeszyty Naukowe Politechniki Śląskiej z. 50, 2010, 51-59.
- [13] **Mičieta, B., Kuric, T.:** Augmented assembly, [in:] Annals of DAAAM for 2009 & Proceedings of the 20th International DAAAM Symposium, Book Series: Annals of DAAAM and Proceedings, Vol. 20, 2009, 499-500.
- [14] **Mičieta, B., Biňasová, V., Haluška, M.:** Reconfigurable manufacturing system and sustainable production, Reconfigurable manufacturing system as the right way to achieving sustainable and energy efficient production 1st edition, Saarbrücken: LAP LAMBERT Academic Publishing, 2014, 86.
- [15] **Tong, J., Zhou, J., Liu, L., Pan, Z., Yan, H.:** Scanning 3D Full Human Bodies using Kinects, IEEE Transactions on Visualization and Computer Graphics, Vol. 18, No. 4, April 2012, 643-650.
- [16] www.developer.microsoft.com.

A PROTOTYPE SYSTEM FOR QUANTITATIVE ASSESSMENT OF VOICE FATIGUE

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Abstract: In this paper we present a prototype system for measuring voice fatigue. Measurement system is equipped with an inertial sensor attached to the neck and a software for analysis of the recorded signals of larynx vibrations. The analysed parameters of the signal are: fundamental frequency and signal power before and after the voice fatigue. In the conducted experiments two groups were distinguished. In the first group there are professional singers, knowledgeable about voice emission techniques whereas in the second group there are individuals who are not using their voice professionally and are not familiar with voice hygiene rules. Analysis of the recorded larynx vibrations and changes of measured parameters show substantial differences between both groups. This fact proves, that the use of correct voice emission technique reduces the risk of voice fatigue or temporal voice disorders and proposed measurement system can be used as a long-term, non-invasive vocal stress monitoring system.

Keywords: voice disorders, voice emission technique, voice fatigue, ambulatory voice monitoring.

Introduction

The voice enables us to communicate verbally with one another. Not only does it have a huge impact on our social life but it is also a primary work tool in such professions as: teachers, singers, actors, journalists, call centres employees and many others. Thus this group of voice working professionals are being far more prone to voice disorders, mainly related to larynx and vocal folds insufficiencies. In addition to this, those people are often not familiar with correct voice emission technique and vocal hygiene rules. Consequently, it can result in temporary or permanent disorders, which can eventually lead to pathologies and harm their speech organs.

The most common reasons to visit a phoniatriest are the following symptoms: hoarseness or breathiness of the voice, limitations in pitch range, voice breaks and limitations in volume [14]. The parameters assessed by laryngologists in non-invasive voice diagnosis are the voice character, the mechanism of voice

production, breathing route, phonation time and fundamental frequency. One of the scales that might be applied to examine the voice is the GRBAS, where consecutive letters are the abbreviations of key indicator names: Grade of hoarseness, Roughness, Breathiness, Asthenia, and Strain [7, 12]. Another indirect method of voice examination is a questionnaire which evaluates the voice disabilities as a Voice Handicap Index (VHI) [6].

The results of the aforementioned voice diagnosis techniques should be confirmed with invasive, laryngostroboscopic examination. In this case vibrating vocal folds are illuminated by a flickering light [2]. Optical illusion (the stroboscopic effect) allows to visualise vibration of the vocal folds in a slow motion. This medical procedure is crucial to evaluate masses or irregularities of the vocal folds which might be early symptoms of their physical stresses and cause of voice disorders [5].

It is said that the development and implementation of long-term, non-invasive examination techniques will be the major breakthrough in diagnosis of the larynx. More and more publications on this topic are being published in both Polish and international scientific literature [8, 11]. This article describes preliminary results of the proposed, long-term, non-invasive vocal stress monitoring system.

Materials and methods

There were four subjects who took part in our experiments. A woman (W1) and a man (M1), aged between 21-24 years, both are familiar with correct voice emission technique, moreover M1 is professional singer. Two other man (M2 and M3), aged between 24-25 years are not exposed to any voice efforts in their jobs and without any knowledge of correct voice emission technique or voice hygiene rules.

The device (Fig. 1a), which was built at the Institute of Electronics [8], is equipped with an inertial sensor which is able to measure laryngeal vibrations along three (X, Y and Z) perpendicular axes (Fig. 1b). Transducer has a 10-bit resolution in a 2g measurement range and a frequency response in a range of 0÷2,5 kHz. The sampling frequency is constant and equals 16128 samples per second.

During the analysis there is a requirement to extract the overall acceleration value $S(t)$, which is the root sum of squares coming from all axes.

$$S(t) = \sqrt{x^2(t) + y^2(t) + z^2(t)} \quad (1)$$

In conducted experiments, the inertial sensor was placed on the subject's neck above the larynx (Fig. 2) with the aid of a hypoallergenic tape. The appropriate placement of the sensor was in the spot in which the strongest vibrations of the larynx occurred during the utterance of vowels and voiced

consonants. The data was saved on the SD memory card embedded in the device. During the measurement sessions device was powered from a USB power bank.

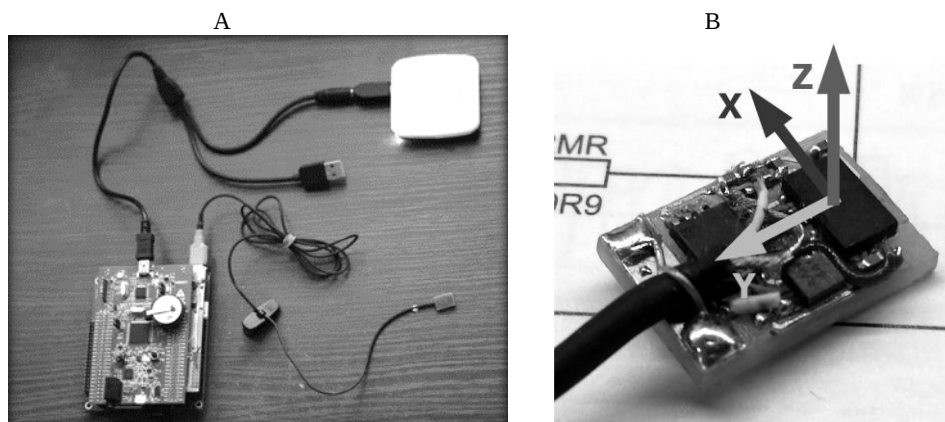


Fig. 1. Device used in the conducted experiments (a), layout of the acceleration axes of the inertial sensor (b)
Source: private source.



Fig. 2. The sensor mounted on the subjects' neck and measuring acceleration signals
Source: private source.

The participant was asked to read a fragment of a text in a quiet place for four minutes. Next, the subjects took part in a 2 hours singing lesson. Such a time duration was sufficient to perceive the differences in the recorded voice parameters between the examined subjects. Afterwards, each subject was asked to repeat the four minutes reading test.

The recorded signals were subdivided into one minute long fragments and band-pass filtered to remove the static (gravitational) acceleration component. All of the intervals or pauses in speaking triggered by taking breath were deleted for further analysis. Data processing algorithms were implemented in the Python programming language with the use of NumPy, Matplotlib, Struct, FFTpack, and Math libraries [4].

The goal was to compare the voice parameters of our subjects measured before and after the voice fatigue: fundamental frequency and overall signal power. Although the average fundamental frequency for women equals to 220 Hz, the range of tones while speaking is 165-255 Hz. For men, the average fundamental frequency, as reported in the literature, equals to 120 Hz and it varies in the range of 85-180 Hz [1]. Signal power parameter, which characterizes the volume of speech, was scaled to decibel units.

Results

The quantitative results of the study are shown in Table 1. The experimental variables were: fundamental frequency and power of the recorded signal for each subject measured before and after the voice fatigue.

Table 1. Parameters describing data registered before and after voice fatigue for every subject. Cells shaded in grey indicate the abnormal results

Time Person	Fundamental frequency [Hz]		Pitch power [dB]	
	Before voice fatigue	After voice fatigue	Before voice fatigue	After voice fatigue
W1	216.52	237.47	36.35	33.43
M1	124.10	130.67	35.52	34.89
M2	120.25	177.45	40.77	41.02
M3	150.18	137.12	38.48	32.27

Source: own study.

The analysis showed the increase of the fundamental frequency after voice fatigue in all but one case. In case of M3, who suffers from asthma, fundamental frequency dropped. This effect was probably caused by his illness. Considering W1 and M1, people who train their voices on a daily basis, the raise of their fundamental frequency is substantially smaller than in case of M2. The smallest increase of this parameter was for M1, whose job involves professional singing. This person is knowledgeable about taking care of correct emission of his voice and voice hygiene rules.

Measured voice pitch power for each subject was expected to decrease after the voice fatigue. The decrease of three decibels means that the signal power is twice as small. Such a case could be noted for W1, while for M3 there was fourfold drop of signal power. The smallest difference between two measurement sessions (before and after the voice fatigue) was visible for subject M1. Unexpectedly, for M2 whose voices' fundamental frequency increased after the voice fatigue, measured voice pitch power also increased. This fact was beyond predicted trend and is discussed below.

Spectrograms of voice signals

Spectrogram plots (Fig. 3 and Fig. 4) were also analyzed for each subject. Spectrogram, or a voiceprint (when voice signals are processed) is a visualization method that shows the phonation process in both time and frequency domains. It is a useful tool for analyzing the voice fatigue and track the changes in spectrum [10]. The colour differences in spectrogram plots indicate large variations of signal amplitudes. The darkest colour presents the highest amplitudes whereas the brighter one denotes the absence of phonation at particular time slots. The white, dashed line visible on the spectrograms shows the fundamental frequency before and after voice fatigue for M2. We can observe on Figure 4, that spectrum around the dashed line is off-balance. In this case M2 had to put more effort to read text after the singing lesson.

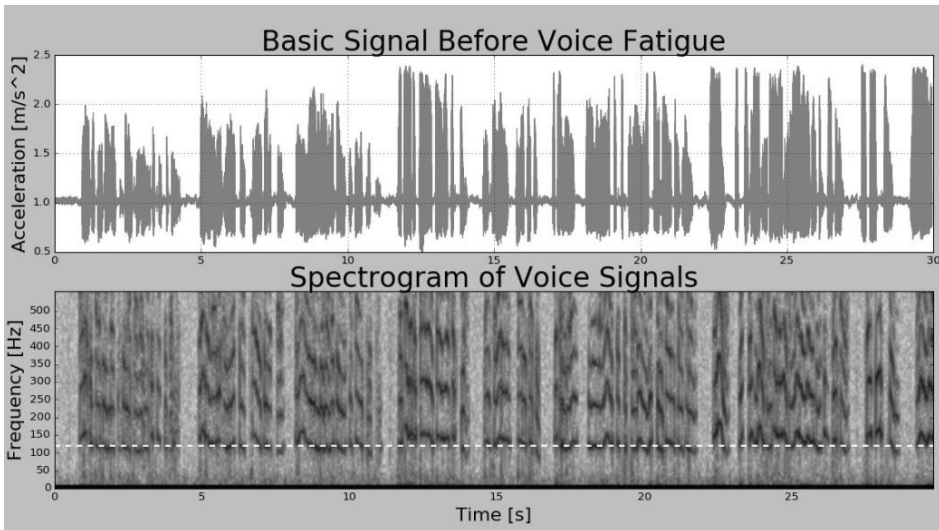


Fig. 3. Voiceprints (spectrogram plots) before voice fatigue for M2
Source: private source.

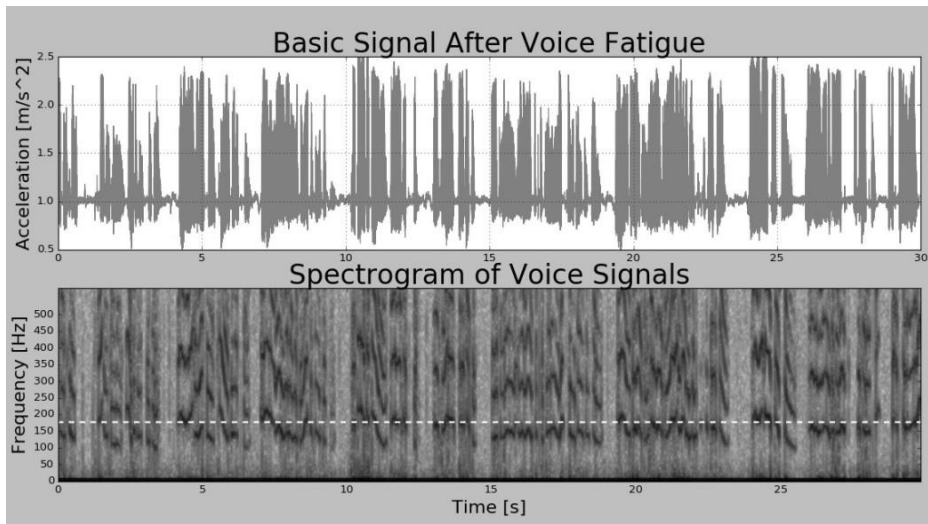


Fig. 4. Voiceprints (spectrogram plots) after the voice fatigue for M2
Source: private source.

Discussion

This research showed that the values of fundamental frequencies for all four subjects were in the range of typical laryngeal tones for both genders. Furthermore, by analyzing results we can say that W1 has one of the highest vocal range of all voice types (classical female singing voice: soprano). The values of voice fundamental frequency for W1 before and after the singing lesson were 216.52 Hz and 237.47 Hz, respectively. Both values are below the upper limit for women voice (255 Hz) [3].

For both subjects who practiced singing, effect of voice load caused by two-hour singing lesson, is much less visible. It is a result of training and correct emission techniques [15] of their voices. The correct posture, singing technique and the way of inhaling and exhaling air are elements which determine the correct work of our speech organs.. It is also a kind of an exercise or a rehabilitation method for people with already developed voice folds dysfunctions [12].

The increase of signal power for M2 could be caused by louder reading of text after the singing lesson. Taking into consideration Figure 3 and Figure 4, which present spectrograms of voice signals before and after voice fatigue, it is clearly seen, that the signal power in Figure 4 is higher. It explains how much more energy the subject had to put into reading the text.

One of our subjects (M3) has asthma. It is a lung disease that inflames and narrows the airways. The factors which generate it are, inter alia, physical effort, cold air, strong emotions (for example happiness, sadness, fear), air pollution, allergens or tobacco smoke. The bronchus wall of the person who has this

disease are thicker. The mucosa in alveolus produce too much mucus which constricts mucosal routes. The strength of the voice depends on the velocity of air [13]. All of the above confirms our findings that the signal power measured for subject M3 declined fourfold after the voice fatigue. The scratching in throat, the necessary hawking, dry cough and the attenuation of voice strength are obstacles in speaking that made the fundamental frequency of his voice to drop [9]. M3 during singing lesson had also cough pauses, therefore the values of the fundamental frequency measured before and after the voice fatigue, are different in comparison to other subjects.

Conclusions

Our voice defines the quality of our personal, social and (in many cases) professional lives. The method of non-invasive measurements of larynx vibrations (from a neck-placed accelerometer) described in this paper can be treated as an early stage of a long-term voice monitoring system. In our preliminary experiments a finite number of measurements were taken only from four test subjects. Despite a limited amount of collected data (two measurements for each subject, before and after the two hour singing lesson) and just two basic voice signal parameters (fundamental frequency and signal power) the described findings are reliable and are encouraging further works and analysis.

People who train their voice, know proper emission technique can better handle voice loads. Discussion of the results with all subjects showed, that even such simple, non-invasive measurements and short experiments can help understand the importance of voice hygiene rules, encourage self-studying and exercising of own voice. Use of inexpensive vocal accumulators (devices which are designed for long-term voice use monitoring) in ambulatories and occupational medicine offices along with voice load analyzing software algorithms will enable more deep and objective studies of our daily voice use, real time monitoring of vocal load and more effective rehabilitation of voice disorders.

In the near future, the authors plan is to develop software algorithms in order to compute, compare and validate not only basic voice parameters but also detect accumulated phonation time, fundamental frequency variations, vocal intensity (correlated with sound pressure levels of a particular user), phonation density and the vocal dose.

References

- [1] **Aronson, A.E., Bless, D.M.:** Clinical Voice Disorders, Thieme, Fourth Edition, 2009.
- [2] Course Voice Emission – Methods of Examination, (in Polish), Nofer Institute of Occupational Medicine, 2005, <https://goo.gl/8S99gu> (last accessed on 6th Oct 2017).

- [3] **Lopatka, K.:** Theory of sound production (in Polish), goo.gl/5h4QHu (last accessed on 9th Oct 2017).
- [4] **Lutz, M.:** Learning Python, O'REILLY, Fifth Edition, 2013.
- [5] **Niebudek-Bogusz, E., Kopczynski, B. et al.:** Quantitative assessment of videolaryngostroboscopic images in patients with glottic pathologies, *Logopedics Phoniatrics Vocology*, Vol. 42(2), 73-83, 2017.
- [6] **Niebudek-Bogusz, E., Strumillo, P. et al.:** Comparison of cepstral coefficients to other voice evaluation parameters in patients with occupational dysphonia, *Occupational Medicine*, Vol. 64(6), 2013, 805-816.
- [7] **Omori, K.:** Diagnosis of Voice Disorders, *JMAJ*, Vol. 54(4), 2011, 248-253.
- [8] **Poryzala, P., Strumillo, P.:** A prototype of a personal, longterm vocal load measuring device (in Polish), *Electronics: construction, technologies and applications*, Vol. 56 (9), 2015, 47-50.
- [9] **Prusakiewicz-Kucharska, S.:** Emission of Voice for Teachers – Allergy and comfort of voice (in Polish), <https://goo.gl/ZyQr3A> (last accessed on 9th Oct 2017).
- [10] **Sataloff, R.T.:** Clinical Assessment of Voice, Plural Publishing Inc., 2005.
- [11] **Schloneger, M.J.:** Assessments of voice use, voice quality, and perceived singing voice function among college/university singing students ages 18-24 through simultaneous ambulatory monitoring with accelerometer and acoustic transducers, University of Kansas, 2014, 7-16.
- [12] **Sliwinska-Kowalska, M., Niebudek-Bogusz, E.:** Rehabilitation of occupational voice dysfunctions (in Polish), Nofer Institute of Occupational Medicine, 2009.
- [13] **Sokolowska-Pituchowa, J.:** Human anatomy (in Polish), PZWL, 2011.
- [14] **Sulica, L.:** MD: Voice Medicine: Voice Disorders, <https://goo.gl/Fn5dVy> (last accessed on 12th Oct 2017).
- [15] **Tarasiewicz, B.:** I speak and sing consciously. Handbook for learning emission voice (in Polish), UNIVERSITAS, First Edition, 2003.

CONCEPT OF THE APPLICATION SUPPORTING VISUALLY IMPAIRED PEOPLE IN PUBLIC TRANSPORT

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Abstract: The subject of the research is support of visually impaired people using a system designed by the author. Presently, in Central Europe, the urban public transport is developing, however, the equal opportunities for handicapped people are not always ensured regarding travelling. For instance, visually impaired people experience hardness on the vehicles as significant part of them is not informing the passengers about the upcoming and current stops through the speakers. Entering to the correct bus is also problematic as they are not able to see the number of the vehicle which arrives to the bus stop. In those cases asking other people for help can be uncomfortable or sometimes even impossible (empty bus or empty bus stop). The TraView application invented by the author provides a solution for such difficult situations for visually impaired people travelling by public transport.

Keywords: disabled, application, visually impaired, mobility, public transport.

Introduction

From the legal point of view blindness means that a person has vision that measures 20/200 or worse [4]. Approximately, 1.8 million visually impaired people live in Poland [5]. People with such impairments face many difficulties in situations from everyday life in environmental, technical and social area. For instance in cities, one of the main difficulties is spatial orientation especially self-navigation outside well-known environments. It is problematic to get to the desired new location or walk along the crowded streets. While traveling by public transport getting off on the proper stop pose great difficulty. Even if the vehicles are new they do not automatically announce names of the upcoming stops due to turned off voice information as it disturbs older people. Entering to the correct bus is another big problem due to which they are obliged to ask for help other people.

Lack of appropriate solutions (technological, organizational, etc.) gave the idea of the TraView application – that is described in the study. The TraView is

an application which aims to increase independence of visually impaired people in moving around the city by accompanying them from the user location until the desired destination. Using the application they should feel more confident while getting to the stops, entering to the correct bus and getting off the public transport vehicles regardless whether they are in a vehicle announcing stops or not.

The idea and requirements of the application were consulted with the Trakt foundation supporting visually impaired people.

Systems supporting visually impaired people

Figure 1 presents systems supporting visually impaired people. The diagram is divided into two levels: Organizational and Managerial Level and Technical and Technological Level. Organizational and Managerial Level covers Systems Supporting Visually Impaired People composed from three groups:

- support at home,
- support at work,
- support outside of home and work.

Each of the group contains various services. For instance one of the Support at Home services are Utilities Service composed of two services: Heating Service and Electricity Service.

In the Technical and Technological Level there are solutions based on the technologies like Internet of Things, Beacons, Speech Synthesizers or Navigation.

Internet of Things (IoT), is “a world where physical objects are seamlessly integrated into the information network and the physical objects can become active participants in business processes. Services are available to interact with these ‘smart objects’ over the Internet, query their state and any information associated with them, taking into account security and privacy issues” [1]. It composes one common system connecting several solutions together.

Continuing the topic of Utilities Service the system for Electricity Service is for example Lighting System, controlling light utilization at home. Lighting System can be connected with Heating System (controlling heating at home) and many others in one common device like smartphone. The device connecting several systems which are interacting together (Internet of Things) should be based on Artificial Intelligence and communicate with the user using Speech Synthesizer or voice recognition. Other technological solutions possible to be used at home are Beacons and Bar and QR codes.

Beacons are Bluetooth radio transmitters which repeatedly transmits a single signal that other devices can see. Instead of emitting visible light, it broadcasts a radio signal that is made up of a combination of letters and numbers transmitted on a regular interval [2]. Beacons can be used for navigation at home helping to find rooms or objects that the user may need. Bar and QR codes placed on the objects facilitates its recognition as well as describing the components of the products, for example, food.

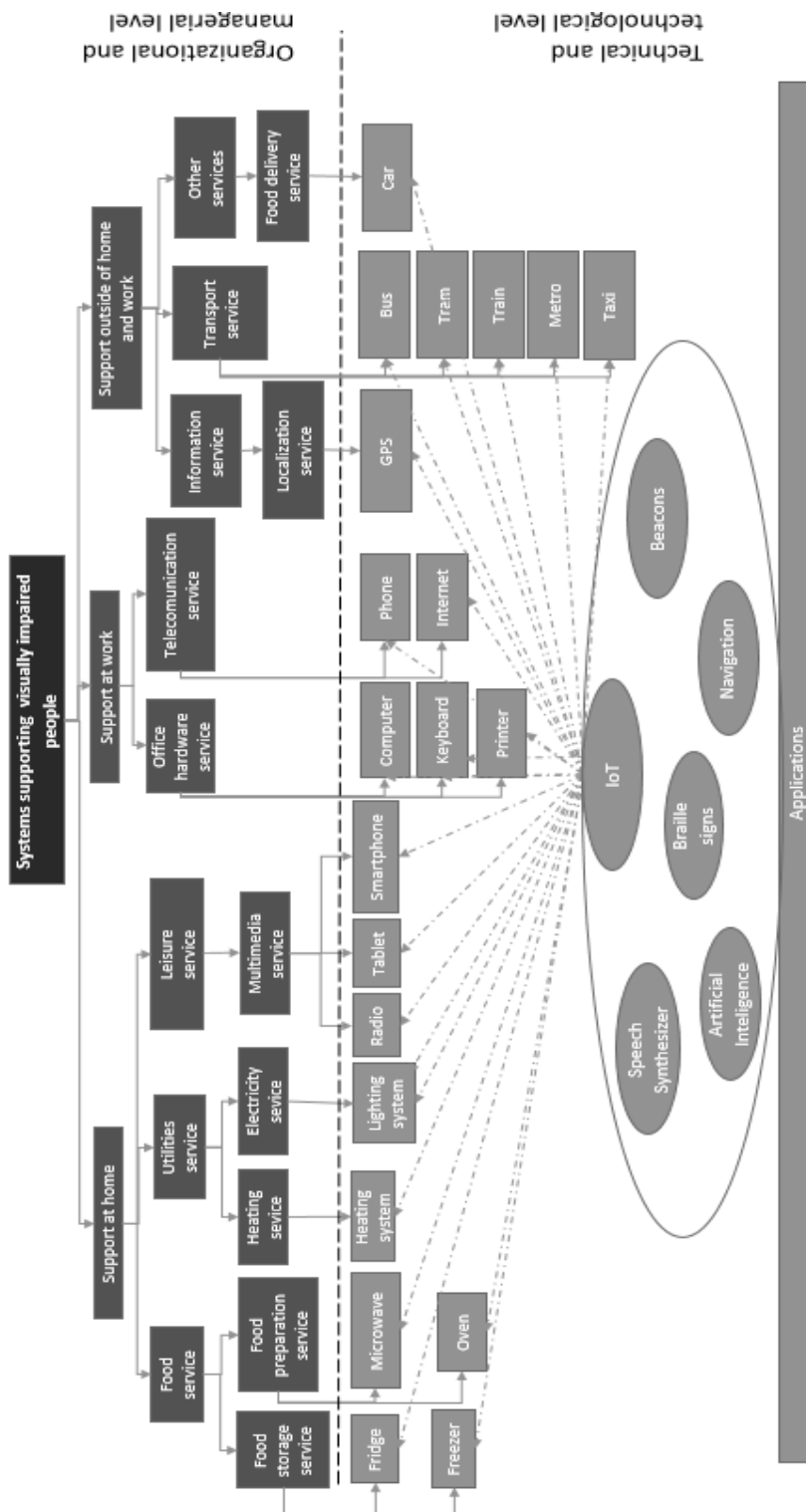


Fig. 1. Systems supporting visually impaired people
Source: own work.

Support of visually impaired people at work is also possible through:

- IoT,
- Beacons,
- Bar and QR codes,
- Compatible Office Software containing Speech Synthesizer and Braille keyboard.

IoT at work can connect printer, computer, telephone and headsets to each other. Beacons allow localization of office rooms as well as objects in the office. Bar and QR codes can be used for the same purpose as at home but more concretely for office objects usually used for work purposes like computer, chair or objects in the office and kitchen allowing the visually impaired person to be independent during lunch break.

In the group of Support outside of home and work there are solutions like:

- Beacons,
- Navigation,
- Speech Synthesizers,
- Travel information systems of public transport.

Beacons may be used for public transport station and flat identification which is useful for navigation to the destination. Moreover, beacons can be placed on Typhlographic maps and also on vehicles of the public transport for indicating when to get inside the bus or other means of transport. Beacons are very innovative and its usage may be very useful. Speech Synthesizer must be a common tool for such solutions.

The TraView application concerns mobility in the city and is placed under the group “support outside of work and home”.

Analysis of solutions already existing on the market

On the market there are already many applications supporting visually impaired people. In the study the analysis of already existing applications on the market has been performed (Table 1). The following applications have been chosen: Seeing Assistant Move, Georgie Bus, Virtualna Warszawa and BeMyEyes.

The Seeing Assistant Move is supporting visually impaired during travel in the city. Using GPS location and navigation it helps to get to the desired location. It is available on Android and iOS.

Application Georgie Bus, available on Android is choosing for its passengers the nearest bus stops and create the path to get there. While traveling by bus it announces the stops the user is passing by, making it easier to get off on the desired stop. It is available only in United Kingdom.

Application Virtualna Warszawa allows navigation around the city as well as in the buildings using beacons placed around Warsaw. It is not in use yet but is still on the testing phase.

BeMyEyes is an application informing users about the name of the object he is staring and becoming the eyes of the user like the name suggest. When help is needed user turns on the application and contact the volunteer currently available. Having camera turned on the volunteer can see and then explain what the user is pointing at.

According to the market research, there is no similar application existing currently on the Polish market which would contain the same features like: planning the route, navigation from the user localisation until the desired point, informing about the bus approaching to the stop based on the real time location of public transport, communicating with the user while travel inside until the help blind people by informing them about the upcoming and the current stop using GPS technology on Android platform. The only place such application exist is the United Kingdom, Georgie Buses. In Poland such application should be implemented the same way with the cooperation with public transport organisations like ZTM in Warsaw.

Analyzing the situation of the TraView application on the mobile application market it has been concluded the product gains a strong position, because it is uniquely innovative.

The concept of the TraView application

The concept concerns TraView application which will support visually impaired passengers traveling by public transport. The following points describe features of the application:

- application will allow users to set desired location and chose the best route from the several proposed by the system,
- navigation during the journey,
- while waiting on the stop it will inform about arrival of the desired public transport vehicle so the user will know when and exactly to which one to enter,
- after user enters the bus the application will inform him/her about the stops, the person is passing by and indicate when to get off,
- when leaving the vehicle application will continue navigation to the set direction (to the exact address),
- the user and the application will communicate with each other using speech synthesizer and voice recognition,
- the first version of the application is planned to work on Android operating system,
- application will be available for all means of transport.

Information about the real time arrival of the public transport vehicle will be supplied from GPS location database shared by Public Transport Authorities or using beacons technology. Both solutions can be used simultaneously for quality assurance in case of connectivity issues.

Table 1. Analysis of applications already existing on the market

Name of the application	Platform	Free/Payed	Available on Polish Market	Means of Transport	Real Time Location of Public Transport	Navigation Solutions	Speech Synthesizer	Voice recognition	Beacon
TraView	Android (iOS planned in the second phase)	Free	Yes	Bus, Metro, Tram, Train	x	x	x	x	x
Sesing Assistant	Android and iOS	Payed	Yes	Bus, Metro, Tram, Train		x	x		
George Bus	Android	Payed	No	Bus	x	x	x		
BeMyEyes	Android and iOS	Free	Yes	-			x		
Virtualna Warszawa	Android and iOS	Free	Testing Version	Bus		x	x		x

Source: own work.

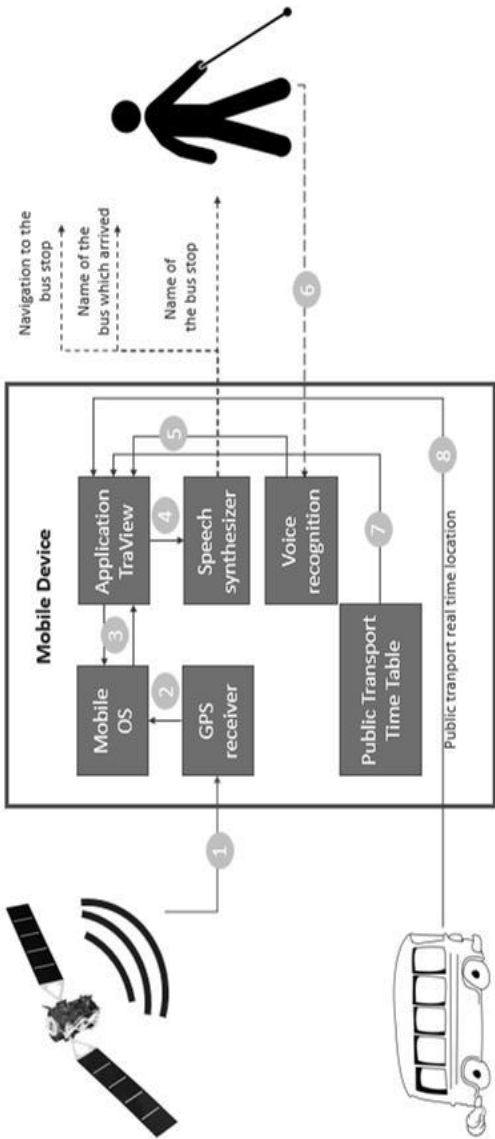


Fig. 2. High Level Diagram
Source: own work.

The biggest value of the application is life facilitation. Passengers using the application will become more independent in their daily routine activities. One of these activities is traveling by public transport. The application will allow the user to get to the desired location without anyone's help, which will increase comfort of visually impaired people. The user will be independent in all kind of means of transport as well as walking on the street. The application will be available free of charge which may be attiring for users as many applications are paid.

The solution is planned to work on mobile devices. Figure 2 presents the High Level Diagram. Application will be formed of several modules inside the mobile device: GPS receiver, Operating System, Application TraView, Speech synthesizer, Voice recognition and Public Transport Timetable. It will interconnect with satellites, collect real time location data of the public transport vehicles and communicate with the end user.

Public transport time table will be the database used for planning the route. Real time location data will need to be shared with the consent of public transport authorities. Based on the GPS coordinates, application will verify the position of the passenger during the navigation from the base location until the destination. When traveling by public transport it will control which stop the vehicle is approaching to. Bus approaching to the stop may be identified via GPS as well as by Beacons.

Speech synthesizer will be used for navigation process and announcing number of the bus arriving to the stop, information about the stops user is passing by and reminding about the target stop. It is the main function thanks to which user may feel comfortable and independent as there is no need to ask other passengers for help.

Possibilities of application development

Application can be built in two ways. The first one is development of the solution from scratch; it means creating every module of the application separately from the beginning. The second option is the Enterprise Service Bus (ESB), being part of the Service Oriented Architecture (SOA) concept. New application can be a connection of the best features from TraView and other already existing applications connected through ESB.

Figure 3 presents the High Level Diagram of the application TraView using ESB. On the figure there is customer segment (user device) and the application being the collection of the best features from different applications.

ESB is an efficient, productive and agile solution allowing communication between mutually interacting software applications. The solution is cheaper and faster than development of the application from the beginning but in the same time requires licenses from the owners. For instance, ESB could join the best ideas from already existing applications like: TraView, Georgie Buses, Seeing Assistant Move, Virtualna Warszawa and form together one common

application. Additionally, some applications which are not used strictly for navigation but for other purposes could be used to form a larger scope like BeMyEyes – it connects the user with the volunteer who may assist and Uber App as well as Uber Eats.

The example of features from different applications which may be connected via ESB to form one common application are the following:

- TraView: availability in all means of transport, voice recognition – ability to communicate with the application using user's voice, vibrations – signalization and beacons technology placed inside the vehicles,
- Georgie Buses: solution informing about buses real time location,
- Seeing Assistant Move: the navigation algorithms to be applied for navigation (from the user location until the destination),
- BeMyEyes: support in cases when eyesight is necessary,
- Virtualna Warszawa: beacons allowing navigation inside the buildings,
- Uber App: enlarging list of means of transport (taxi),
- Uber Eats: application for ordering meals.

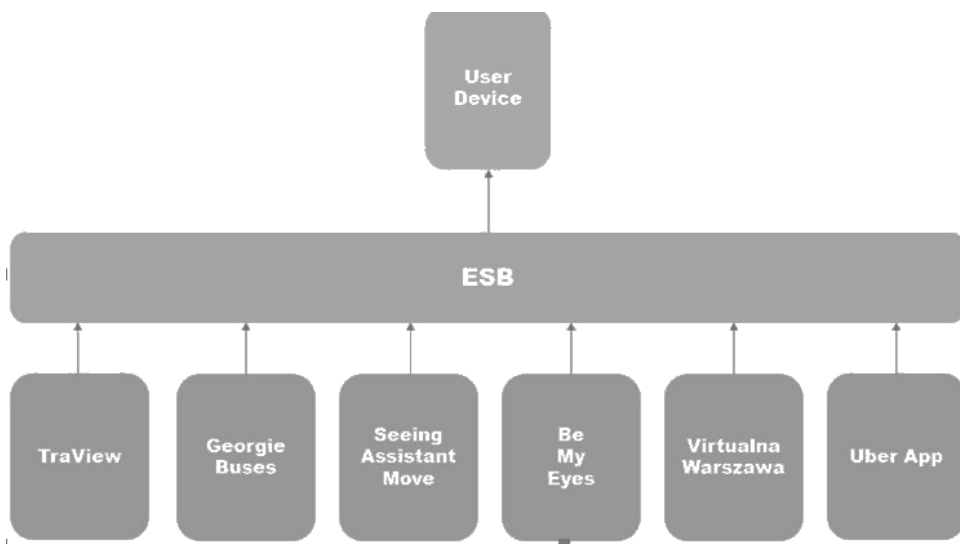


Fig. 3. High Level Diagram of the application TraView using ESB

Source: own work.

ESB can be an easy solution for the future to attach new ideas in the scope.

Application is planned on Android system as it is used by the majority of smartphone users [3]. In 2017, Q1 85% of users chose Android. In the future improvement of the application could also be deployed on iOS being the second most famous system in the world.

The development of the application should focus on navigation inside and outside the buildings which may base on previously mentioned beacons

technology. It is particularly useful in cases when GPS technology fails or in many other solutions such as the border of the pedestrian crossing.

Conclusion

The TraView application reduces mobility barriers of visually impaired people. There is no such application on the market containing all the features of the TraView application and in the same time being available free of charge. There are two options of development in terms of building the application: from scratch or using ESB which is cheaper and faster but requires licenses from the owners. In the first phase the application is planned for Android platform but in the future it could be deployed also on iOS.

Beacon is a future technology for solutions supporting visually impaired people. It could be used inside of buildings and public transport vehicles where the functionality of GPS is limited or in many other solutions such as the border of the pedestrian crossing. All of these solutions can be collected and placed in the proposed application – TraView.

References

- [1] **Haller, S., Karnouskos, S., Schroth, C.:** The Internet of Things in an Enterprise Context, 2009, 15, 2009.
- [2] <https://kontakt.io/beacon-basics/what-is-a-beacon/> – accessed on 10.09.2017.
- [3] <http://www.idc.com/promo/smartphone-market-share/os> – accessed on 07.08.2017.
- [4] <https://www.livestrong.com/article/241936-challenges-that-blind-people-face/> accessed on (15.11.2017).
- [5] Rynek Zdrowia (2017). <http://www.rynekzdrowia.pl/Uslugi-medyczne/W-Polsce-zyje-az-1-8-mln-niewidomych-lub-slabowidzacych,155889,8.html> – accessed on 10.09.2017.

IDENTIFICATION OF THE PERCEPTIVE AND MOTOR SKILLS IN ELDERLY PEOPLE WHEN DESIGNING A HUMAN-COMPUTER INTERACTION

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Abstract: Concerns of human-computer interaction for users with specific requirements are presented in this papers. Problems of elderly people using computer devices are here described. Application of the assessment method for perceptive and motor skills in elderly people is presented – survey, DASH questionnaire and Colour Test of Relations. It is demonstrated in the results for limitations, that elderly people have higher diversification of the coordinative and motor skills, when compared to young people. Despite the existing trend for weakened elderly people skills, any significant correlation between the assessment for upper limbs functions and mild cognitive disorder was not demonstrated. Only a slight relation between the age versus the existing maladies and general assessment of elderly possibilities was observed. An exemplary approach for application of data on diseases, maladies and illnesses of elderly people in identification of ergonomic requirements is here proposed. Researches were made on a group of people in the age of 20-30 and on a group in the age of 63-87.

Keywords: ergonomics of elderly people, Human Computer Interaction, coordination of motor skills of elderly people.

Introduction

Altogether with rapid technical advancement and development of medical sciences in the world, there are rapid changes in demographic structure – population of elderly people is increasing.

Elderly people, who have many times rich life's experience and knowledge, unfortunately often fear of and are unwilling for modern computer devices, that currently dominated the world. Lacking skill in using such items, that are currently daily necessities, i.e. mobile phones, cash machines, computers or digital cameras, makes that seniors are alien to contemporary world [11].

The most often declared problems in such area are related with using hand-held controller devices, such as computer mice, as well as with learning of numerous functions available both from the keyboard level (shortcuts) and in the area of particular software (i.e. setting in Word). They have troubles in the

obligatory memorising of the sequence of operations, that are scarcely intuitive and too abstract from the perspective of elderly people, thus such sequences are hard in memorising and application, require good memory and precision in application (particularly precision and caution). Using the computer and Internet generally tends to be troublesome for elderly people in such areas, that definitely differ from their knowledge of daily life; maybe this is why a logging procedure or using a mouse is so troublesome, whereas surfing on the web or writing is not [17].

The researched people also reported difficulties in using a phone. Too small buttons, the excessive number of unrequired options in the menu, what obstructs the device's use, too small size of text displayed on the screen and phone's size disabling keeping it in a hand and efficient read-out of a text, all of this results in particular difficulties.

Elderly age should not mean the forced lack of access to modern devices and lacking opportunities for information in daily life [9, 12, 14, 15, 16, 18, 19]. It is demonstrated in some researches, that there is a still great percentage of elderly people without access to the Internet. Using the computer by elderly people enables the improvement of lifestyle and its quality.

On the basis of the presented research results, it can be demonstrated that more and more seniors use computer, the Internet and mobile phone, despite the existing barriers in the use of modern devices by elderly people. Frequency of use for modern devices and skills for its use is the higher, the younger is the researched person. However, problems experienced by elderly people when using computer devices result from maladjustment of technique to the psychomotor skills of elderly people.

The purpose of research provided in these papers is identification of psychomotor skills of elderly people and assessment of opportunities for application of knowledge about coordination of elderly people motor skills, when formulating ergonomic requirements in the shaped human-computer interactions.

Method and extent of researches

Researches were conducted with means of survey, DASH questionnaire and Colour Trails Tests – CTT.

Open questions were included in the survey (with exemplary responses) for three areas of existing diseases, maladies and illnesses, namely organ of sight, locomotor system and central nervous system. Respondents were additionally asked for i.e. sex, age, education and residential place.

DASH questionnaire was used for identification of functional dysfunctions of upper limbs. Whereas, Colour Trail Test was used for identification of mild cognitive disorders related with the performed motor tasks. Both methods are described in the following subsections.

The research covered two research groups: young people (in the age of 20-30) and elderly people (in the age of 63-87). 19 women and 11 men were in the

group of young people, whereas 23 women and 3 men were in the group of elderly people.

Educational level for both groups was diverse and is presented below:

- young people: secondary (36.67% of people) and higher (63.33% of people),
- elderly people: primary (7.7% of people), vocational (15.38% of people), secondary (61.54% of people) and higher (15.38% of people).

All elderly people declared, that they reside in a big city. Whereas, 20% of young people resided in cottages, 30% resided in town and 50% resident in big city.

Young people included in such researches are employees after secondary schools, students or university graduates with own business activity. All elderly people who participated in the researches belong to the senior club or are in close relations with senior clubs.

DASH questionnaire

DASH questionnaire (Disabilities of Arm Shoulder and Hand) is the self-assessment questionnaire with 30 items concerning functioning of upper limbs. In the assumptions, an upper limb is treated as a functional wholeness, in which a functional disorder of one its part influences in a significant manner on the whole upper limb, as well as on daily and social activity [1].

The questions concerned problems with operations made with means of upper limb, related with physical activity (21 questions), increase in the suffered pain, numbness, weakening and stiffness of a limb (5 questions), as well as influence of disabled functions of such a limb on social activity, work, sleep or cognition of own person. Every question has 5 possible responses, from lacking disability of functions to maximum limitation of a function or exacerbation [6]. The collected responses are summarised in the provided scale from 0 (correct functioning) to 100 (maximum disability of a function). This factor is evaluated according to the formula:

DASH factor = $*(\text{the sum of response points/number of responses}) - 1] \times 25$

Dash questionnaire is used in the assessment of diseases for upper limbs, generally for the assessment of surgical therapy results. Assessment can cover damages at every level of a limb, from pectoral girdle to fingers, and even influence of spinal changes on the functions of limb [5]. Specific response patterns were separated for several types of diseases [10].

Groups of questions can be separated in the scope of questionnaire, that respond to the International Classification of Functioning, Disability and Health, ICF for the impairment of body functions or psychical functions, limitation of activity and participation in daily life [8].

According to the settled division, questions from 1 to 16 are for the impaired activity, with exclusion to question 10, that cannot be classified in any group. Questions 20 and 22 are for participation impairments. Questions from 17 to 19 and 21 and 23 are both for the impairment of activity and participation; it means that questions 1-9, 11-19, 21, 23 are for activity impairments, whereas questions 17-23 are for participation impairments. Questions from 24 to 28 are for functional impairments. Questions 29 and 30, similarly to the question 10, cannot be classified in any group [8].

Colour Trail Test

Colour Trail Test is a simple, short vision and motor test (pencil and paper type), comprising of two parts, that on grounds of its construction requires the knowledge of numbers from 1 to 25 and graphomotor skills. In the first part of the test (CTT-1), such task is based on the possibly quickest connection of the string of numbers, whereas in the second part (CTT-2) on the connection of the string of numbers with inclusion of alternating colours. When solving both CTT parts, various processes related with cognitive functions are involved, namely capacities of: purposeful skipping through the material, keeping and shifting the focus, sequential processing the information and monitoring own behaviour. CTT is a very sensible tool for detection of disorders in the cognition processes and cognitive functions [13].

Colour Trail Test is designed for testing adults. CTT comprises of two parts: CTT-1 and CTT-2, that are handed over to a tested person one directly after another. Every such part contains colour (pink or yellow) circles, in which the numbers from 1 to 8 (trial test) and from 1 to 25 (proper test) are provided. In CCT-1 all odd numbers are printed in pink circles, and even numbers are in yellow circles. In CTT-2 every number is printed twice, once on the pink background and once on the yellow background. Test tasks are located on two sheets of white paper, wherein on first side of every sheet trial tasks are located, and proper tasks are placed on the opposite side. The sequence for making the CTT is as follows: trial task in CTT-1, proper task in CCT-1, trial task in CCT-2, proper task in CCT-2 [13].

An elderly person is required for connection of numbers with straight lines, without taking off the pencil from the paper, in the ascending order, wherein in CCT-2, the numbers should be connected in such a way, that alternate colours should be combined. Time measured by a psychologist is basic factor (in sec.) for tasks pursued in every test. Moreover, in every test additional factors are recorded [7]:

- faulty sequence of numbers (and in CCT-2 also faulty sequence of colours), referring to the faults made,
- nearly a fault, referring to the cases of a correction made by an examined person for the formerly placed incorrect reaction (auto-correction),

- advices, referring to the psychologist's aids provided for an examined person (indication of the following item).

The result of disturbance indicator informing about the influence of disturbing factors on the speed of work is additionally evaluated.

Test results

Both research groups were characterised with various diseases, illnesses and maladies in the area of organ of vision, locomotor system and central nervous system, and precisely (Figure 1): long sight (1), short sight (2), astigmatism (3), stinging in eyes (4), dry eyes (5), watery eyes (6), cataract (7), macula (8), cataract (9), strabismus (10), glaucoma (11), damaged optic muscle nerve (12), depression and anxiety (13), stroke (14), memory problems (1%), problems with concentration (16), dysgraphia (17), problems with spatial orientation (18), problems with manual functions (19), problems with keeping proper body balance (20), muscle spasms (21), weak and flaccid muscles (22), skin hypersensitivity (23), neck pains (24), elbow pains (25), wrist pains (26), stiffness in hands (27), stiffness of fingers (28), deformation of a hand (29), deformation of fingers (30), wrongly assembled elbow (31), rheumatism (32) and damaged spine (33).

From 33 illnesses in total, 4 illnesses existed only in young people and it was: astigmatism, strabismus, depression and anxiety, as well as dysgraphia. In other categories, elderly people more frequently reported particular illnesses. One fact is particularly interesting, namely two young people: one with depression and anxiety, another one with dysgraphia, who obtained the CTT results similar to the elderly people with better results.

A significant correlation ($r^2 = 2,96$) has not been provided between the results for functional limitations in upper limb and cognitive limitations in elderly people.

On the basis of dispersion graph for limitations in psychomotor skills, it can be demonstrated that:

- dispersion from the assessment of elderly people is greater, than for young people,
- statistically, elderly people have lower psychomotor skills, when compared to young people,
- a significant proportion of elderly people has lower results than young people with diseases, particularly with i.e. depression and anxiety, strabismus, dysgraphia or lowered skills of making manual activities.

Dispersion of assessment results with means of DASH and CTT questionnaire is presented on the Figure 2.

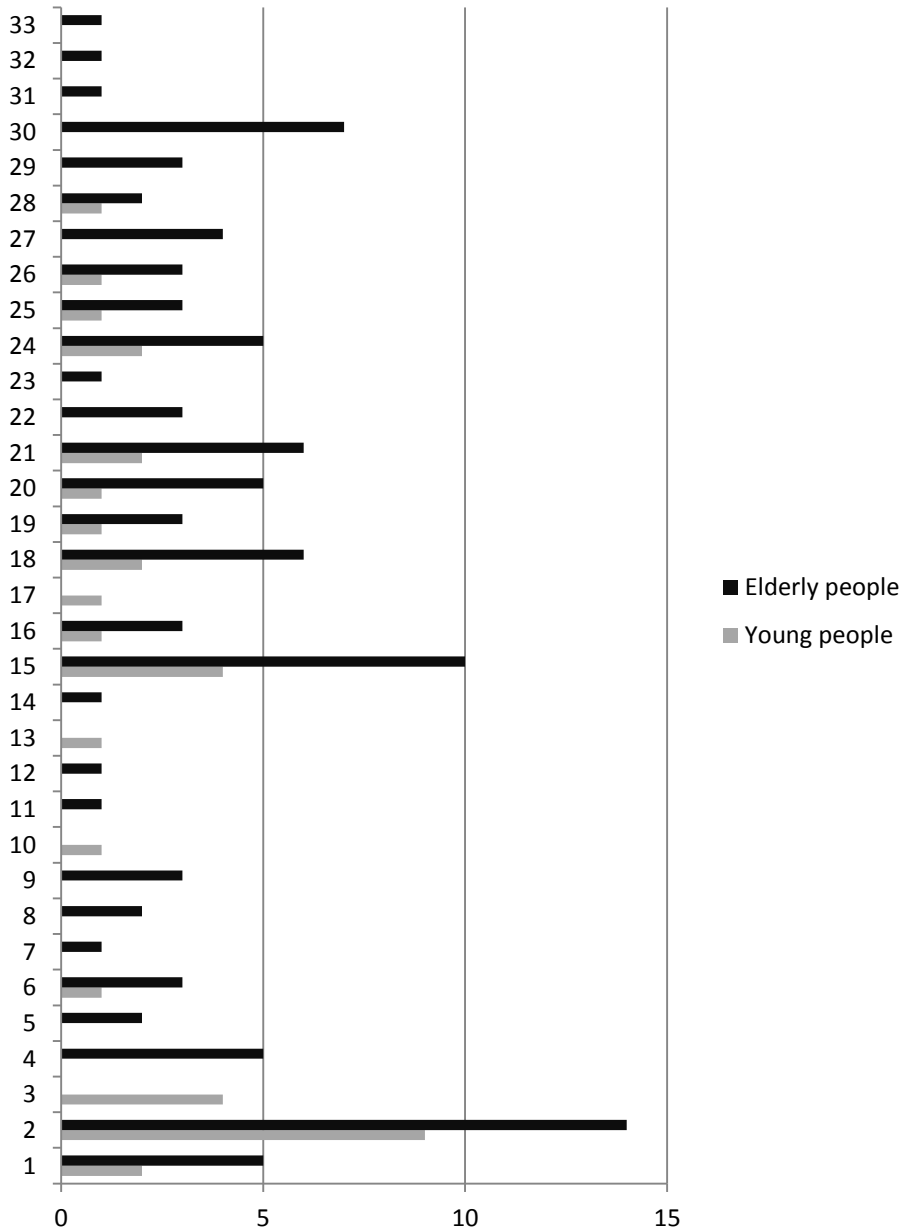


Fig. 1. Disease, illnesses and maladies in young and elderly people
Source: own elaboration.

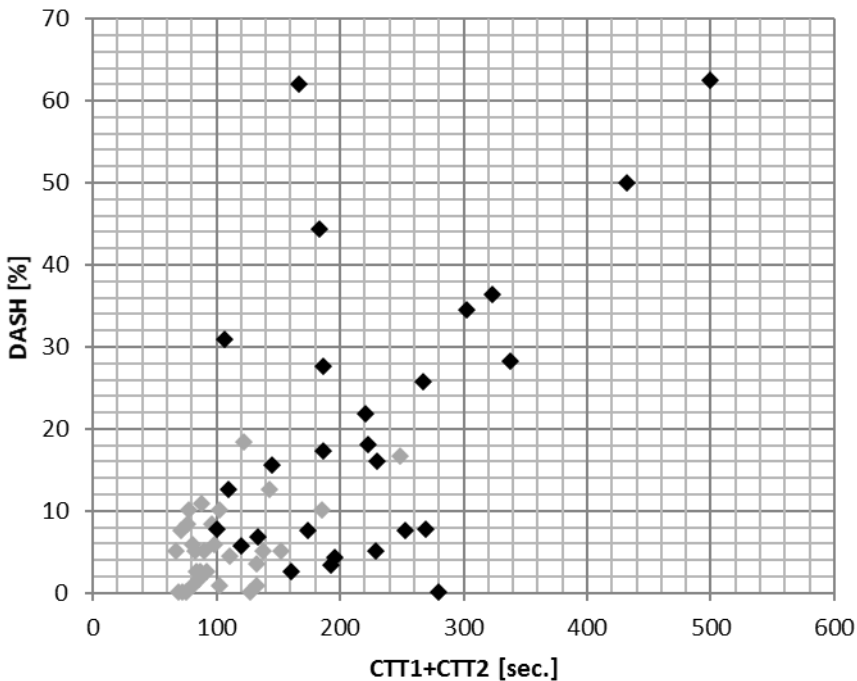


Fig. 2. Dispersion of assessment results with means of DASH and CTT questionnaire (time CTT-1 + CTT-2)
Source: own elaboration.

According to the DASH questionnaire, elderly people reported lifting heavy loads (exceeding 5 kg), recreational activities, at time of which vast movements without a weight are made (i.e. ringo game, badminton etc.), recreational activities, at time of which a limb, a shoulder or a hand is loaded (i.e. golf, tennis, hammering nails etc.), placing items on a shelf located above the head, opening a firmly closed or new jar and carrying a bag with shopping or a briefcase as most difficult. Whereas, the respondents indicated that putting pullover over the head or recreational activities not requiring a large exercise (i.e. playing cards, crocheting etc.) do not make problems at all. Respondents also reported a significant influence of illnesses occurring in last week in the pursued profession and daily activities and on the significant pain in the hand, shoulder or palms (as well as when making particular activities) and weakening of a hand, a shoulder or a palm. Elderly people also feel considerably weaker, less fit and less useful. Whereas, illnesses do not strongly influence on social activity and sleep of elderly people, whereas the following illnesses, such as strong formication (numbness) and stiffening of upper limb, occur scarcely.

Results for CCT additional factors (Table 1) demonstrate considerably higher difficulties and limitations of elderly people when making tests.

Table 1. Results for CCT-1 and CCT-2 additional factors

Factor	CTT-1		Factor	CTT-2	
	Young people	Elderly people		Young people	Elderly people
Incorrect sequence of numbers	1	5	Invalid sequence of numbers	2	1
Factor	CTT-1	Factor	CTT-2	Factor	CTT-1
	Young people	Elderly people			Young people
Almost error	8	11	Incorrect color order	4	8
hint	2	9	Almost error	8	22
			hint	2	58

Source: own elaboration.

It doubtlessly proves the considerably lowered motor skills for coordination on the cognitive background. Elderly people in CCT-2 required even 58 hints, in relation to 2 hints for young people. As well as in CCT-1, elderly people obtained worse assessment results.

Knowledge of illnesses versus ergonomic requirements

Elderly people are doubtlessly characterised with lowered perceptive and motoric skills, when compared to young people. The performed assessment for elderly people skills, with means of DASH and CCT, was the assessment on general level. This level demonstrates great differentiation of results, what is problematic when transferring to ergonomic requirements. Thus, application of more detailed approach to formulation of ergonomic requirements tends to be important.

Such an approach may be oriented on the illnesses of elderly people, that are located in a particular body part, for which a particular level of inconvenience is reported by the researched person. On the basis of the inconvenience assessment, the most burdensome inconvenience for an elderly person should be selected. The selected inconveniences are analysed towards their influence on coordination motor skills. When the influence on the coordination motor skills is known, the influence of the inconvenience on the created difficulties in the interaction of elderly person with a manual controller device can be assessed (type of RUS for the pursued test should be previously selected).

Priority is given to the identified difficulties in interaction, and following this the most important usage assumptions are formulated (with means of technical solutions). In the following step, ergonomic requirements should be determined, that can be called as standard, because they are based on norms and recommendations oriented on a standard user. When determining particular ergonomic requirements, a dependence matrix for requirement categories should

be taken into account. The proposed approach ends up with the detailed RUS functional and ergonomic model. The proposed approach is presented on Figure 3.

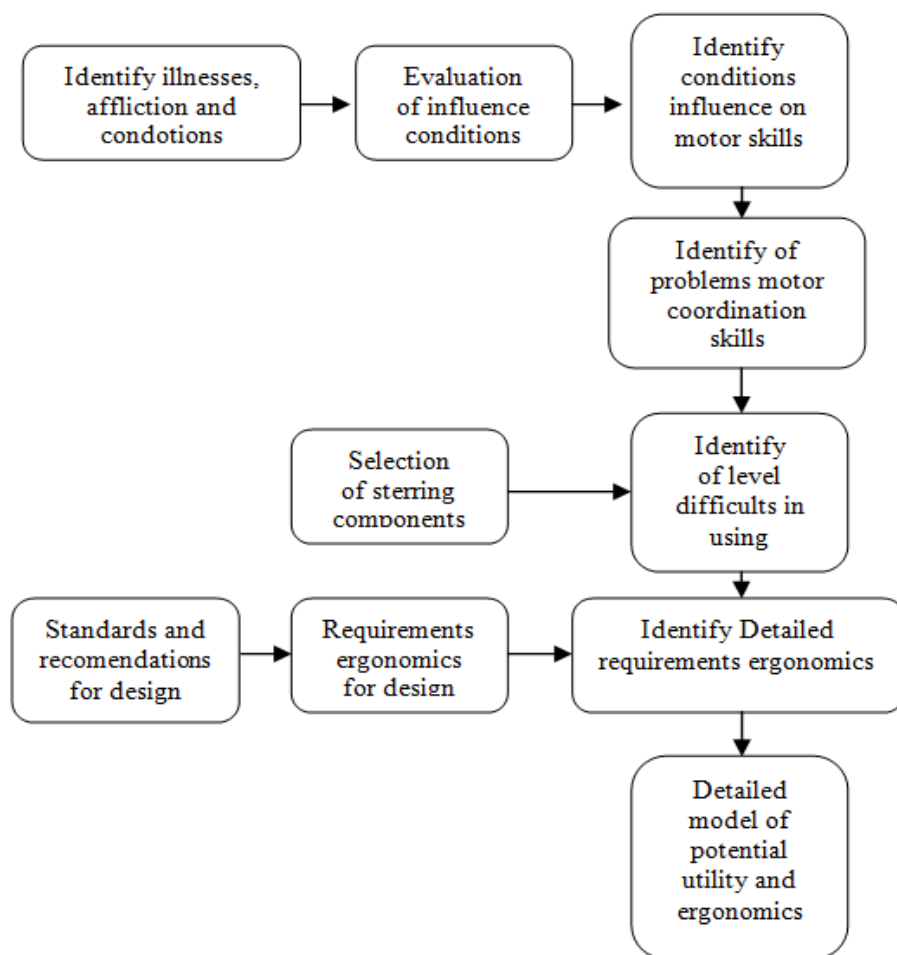


Fig. 3. Diagram for application of inconveniences when identifying ergonomic requirements
Source: own elaboration.

On Figure 4, the simplified example of applied identification of individual inconveniences for elderly people is presented, for formulation of ergonomic requirements. In the whole process, proper determination of difficulties related with particular types of coordination motor skills versus the inconveniences in the usage context is important. The second very important step is proper determination of technical solutions limiting the chances for difficulties in the interaction of elderly person with a manual controller device.

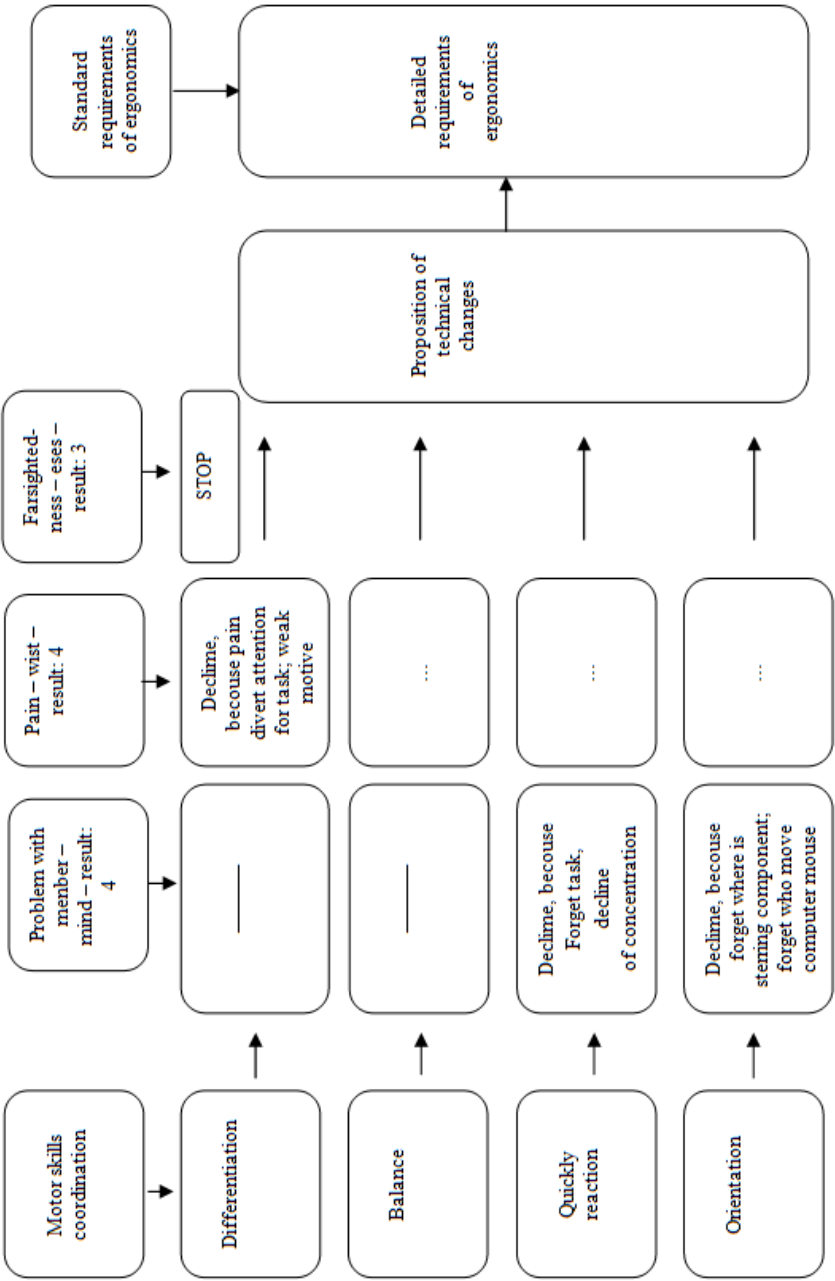


Fig. 4. Simplified diagram for formulation of ergonomic requirements with means of application of knowledge about inconveniences
Source: own elaboration.

Proper execution of the presented approach should guarantee the range of technical solutions, that should provide new ergonomic quality and innovation in application.

Conclusions

Elderly people undoubtedly use computer devices in more and more broad scope, that have insufficient ergonomic quality. It is manifested in difficulties and isolation of elderly people. There is a great need for properly formulated ergonomic requirements for manual controller devices, in response to the elderly people capabilities. Adaptation of manual controller devices to elderly people is similarly important to adaptation of graphical interface, because both components create conditions for interaction, when using a computer device.

The purpose of this papers is obtained with means of the identified psychical and motor limitations influencing on the capabilities of elderly people. The results are provided in detail for the existing inconveniences, as well as in detail for the DASH and CTT assessment.

The results demonstrate, that elderly people are characterised with a greater diversification of illnesses and more frequent and stronger burden from illnesses. Elderly people usually suffer from several chronic diseases. The existing inconveniences in the area of upper limbs influence on the performed daily activities and professional occupation, generally on the professional seclusion. The analysis for DASH and CTT results demonstrates that the core of the problem is significant dispersion of this concern and lacking rules supporting determination of ergonomics for manual controller devices for elderly people.

In order to solve this problem, the approach based on the analysis of individual inconveniences of elderly people is proposed. Such approach is presented on the simplified example.

References

- [1] **Alotaibi, N.M.:** The cross-cultural adaptation of the disabilities of arm, shoulder and hand (DASH): a systematic review. *Occup Ther Int* 15(3), 2008, 178-190.
- [2] **Beaton, D.E., Katz, J.N., Fossel, A.H., Wright, J.G., Tarasuk, V., Bombardier, C.:** Measuring whole or parts? Validity, reliability, and responsiveness of the disabilities of the arm, shoulder and hand outcome measure in different regions of the upper extreimity. *J Hand Ther* 14:2, 2001.
- [3] **Ceynowa, M.:** Ocena funkcji kończyny górnej po leczeniu urazowych uszkodzeń nerwu pośrodkowego, Łokciowego i promieniowego, Praca na stopień doktora nauk medycznych, Gdański Uniwersytet Medyczny, Gdańsk 2010.
- [4] **D'Elia, L.F., Satz, P., Uchiyama, C.L., White, T.:** Kolorowy Test Połączeń, Podręcznik dla specjalistów, Pracownia Testów Psychologicznych Polskiego Towarzystwa Psychologicznego, Warszawa 2012.

- [5] **Dixon, D., Johnston, M., McQueen, M., Court-Brown, C.:** The disabilities of the arm, shoulder and hand questionnaire (DASH) can measure impairment, activity limitations and participation restriction constructs from the International Classification of Functioning, Disability and Health (ICF). *BMC Musculoskeletal Disorders*, 9:114, 2008.
- [6] <http://www.imsero.es/InterPresent2/groups/imsero/documents/binario/infppmm2008.pdf>
- [7] **Jester, A., Harth, A., Wind, G., Germann, G., Sauerbier, M.:** Disabilities of the arm, shoulder and hand (DASH) questionnaire: determining functional activity profiles in patients with upper extremity disorders. *J Hand Surg (Br)* 2005.
- [8] **Kędziora-Kornatowska, K., Grzanka-Tykwińska, A.:** Osoby starsze w społeczeństwie informacyjnym,, Tom 19, nr 2, *Gerontologia Polska* 2011, 107-111.
- [9] **Kurniawan, S.:** Older people and mobile phones: a multi-method investigation. *International Journal of Human-Computer Studies* 66, 2008, 889-901.
- [10] **Łojek, E., Stańczak, J.:** Kolorowy Test Połączeń wersja dla dorosłych – CTT, Podręcznik, Polska normalizacja, Pracownia Testów Psychologicznych Polskiego Towarzystwa Psychologicznego, Warszawa 2012.
- [11] **Morrell, R.W., Mayhorn, C.B., Bennett, J.:** A survey of World Wide Web use in middle-aged and older adults. *Human Factors*, 42, 2000, 175-182.
- [12] **Segrist, K.A.:** Attitudes of older adults toward a computer training program. *Educational Gerontology*, 30, 2004, 563-571.
- [13] **Szmigielska, B., Bąk, A., Jaszcak, A.:** Komputer i Internet w życiu e-seniorów – doniesienia z badań jakościowych, *Studia Edukacyjne* Nr 23/2012, Uniwersytet Jagielloński w Krakowie, Kraków 2012.
- [14] **White, H., McConnell, E., Clipp, E., Branch, L.G., Sloane, R., Pieper, C.:** A randomized controlled trial of the psychosocial impact of providing internet training and access to older adults. *Aging and Mental Health*, 6, 2002, 213-221.
- [15] **Xie, B.:** Older adults, computers, and the Internet: future directions. *Gerontechnology* 2, 2003, 289-305.

THE SIMULATION OF CORPORAL EXPERIENCES AS A STRATEGY FOR THE ELDERLY INCLUSION IN THE DESIGN PROCESS

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Abstract: Although there are several implementations and ways of carrying out a simulation, this text will emphasize on the usage of this tool within the product design and development environment. While this topic is generally performed in the testing phases, it's important to encourage simulations in order to fully assimilate design issues and the features of the User – Object – Context system since the early stages of development. All this process is done to avoid errors in the way a designer interprets the information found in literature as inputs or design guideline [5, 9, 13, 14, 15, 23]. Based on this approach, the Ergonomics Research Line of the Industrial Design Faculty of the Universidad Pontificia Bolivariana, propose the development of the research Project, whose general objective is to develop a system of elements that allow the designer to simulate functional states of users with particular physical characteristics. In this case the user of the elderly was approached as the theme of the project.

Keywords: Pedagogical-tools, Simulation, Product-design, Elderly, Product design-specification, Simulation suit-Industrial design.

Introduction

Information and Communications Technology (ICT) has had its biggest impact in the field of science education, helping students at different stages in their schooling and improving the performance of teaching staff [19]. Included in these educational technologies and methodologies are simulation techniques, which are used to improve the performance of a particular system and broaden its application to cover different pedagogical disciplines and approaches.

Simulation techniques allow students to inhabit a context that replicates some aspect of reality, and establishes within this context certain situations, activities and/or problems that correspond to real life. The use of simulation enhances and accelerates the quality of the student learning process, systematically integrating itself into the pedagogical model [16].

Simulations can be used and applied in a variety of ways, including sensory information gathering, context-based laboratory work and training in different disciplines such as engineering, medicine and construction [19]. This paper, however, will focus on the use of simulation in product design and development.

Moreover, although this technique is commonly used during the testing phase of a project (once a prototype or at least a tangible product idea has been developed), it is important to use simulation in subsequent phases to improve understanding of those variables inherent in the design process, such as human factors and the relationship with the object and the context of use. This will enable students to accurately define the possible requirements of the user.

Simulation as a concept in the learning process

According to the Real Academia Española (Royal Spanish Academy), to simulate means to “represent something, by pretending or imitating what is not”. However, from a pedagogical perspective, a better definition of simulation is provided by Cristina Davini and Litwin, who understand it as “a teaching method aimed at familiarizing students with situations and features similar to those found in reality, but which actually exist artificially. The objective is to train students in the practical and operational skills that they require to adapt those situations and elements to the real world [6, 10].

Simulation can recreate situations and establish experiments thanks to the visualization of a physical system and the link between reality and abstraction. This helps create a dynamic and interactive learning environment during the entire student learning process. Simulation also helps explain and illuminate a particular topic by acting as a support mechanism and collaborative learning tool to establish necessary conceptual foundations, or to reinforce what has been learnt in the classroom [12]. This motivates the student and encourages greater participation; at the same time skills are developed to visualize the consequences of certain decisions, and to practically apply theoretical knowledge [8].

As part of the learning process, simulation can be used at two key moments: during the teaching-learning process, and at the evaluation phase. In addition to providing techniques for diagnosing, treating and solving problems, simulation can help improve psychomotor and relationship skills more efficiently than other methods by focusing the student’s attention on a clear objective, and then reproducing it as part of a standardized process. In the evaluation phase, simulation helps measure data search capability and interpretation, and assess the types of problems raised during the activity [4].

Applications and approaches of simulation as a pedagogical strategy

Different types of simulation techniques exist, and will vary according to their application, resources, objectives and required expertise. The following types can be high-lighted: (i) three-dimensional simulators, such as cardiorespiratory, multipurpose, obstetric, etc., which emit signals from a system that allow medical students to diagnose a particular scenario; (ii) visual and/or auditory stimuli, used in any given discipline or stage of education, and which focus on

the human senses to obtain information; (iii) computer-aided simulation, used in disciplines such as design, medicine, engineering and construction to generate 3D models based on an initial idea; (iv) the simulation of a theory using case studies, applying concepts to a real-life situation [4, 18].

The concept of simulation as a pedagogic strategy has been used a lot more in the area of healthcare, specifically to: (i) define a student's level of clinical competence; (ii) assess the effectiveness of a study plan according to a particular objective; (iii) understand beneficial habits and skills that can be used with healthy and sick individuals, reducing pain and discomfort, especially when dealing with large groups; (iv) carry out practices similar to real-life interaction in a particular occupational area; (v) examine reproductive techniques, algorithms and problems to help foster habits and skills; (vi) perform scientifically applied maneuvers and procedures, both under supervision and independently; (vii) link the understanding of clinical, diagnostic and therapeutic techniques and procedures with real life situations, as well as complementing them with other teaching methods [1, 17]. The area of healthcare has been fundamental in the development and evolution of simulators; the first simulator devices were used in anesthesiology, such as the Resusci Anne manikin (Fig. 1a), designed by Asmund Laerdal (Fig. 1b) and Sim One (Fig. 1c) designed by Abrahamson and Denson [11, 20].

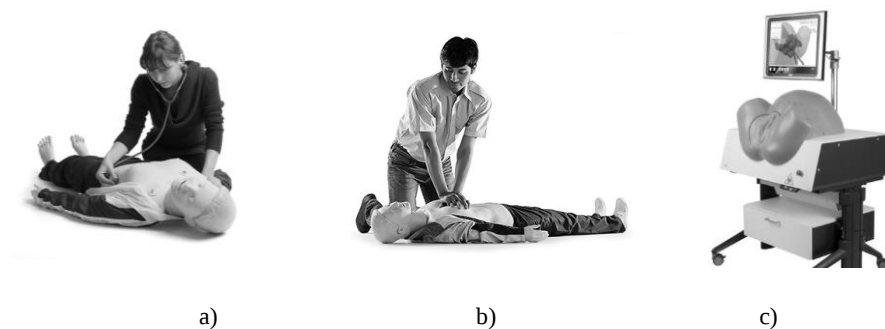


Fig. 1. Examples of simulators used in medicine a) Resusci Anne, b) Asmund Laerdal, c) Sim One

Source: [11, 20].

Simulation as a tool in product design

The conceptualization and testing phases of product design and development employ a number of different simulation tools and techniques, such as constructive interaction, mock-up, role play, resource flux, user proof, OCRA, RULA, walkthrough analysis and others. These tools and techniques should also be implemented in earlier phases that seek to gather and analyze information relating to the user-object-context system. Typically, these phases are the most demanding for a designer in obtaining explicit, observable, tacit, and latent

knowledge of the user. These phases also provide opportunities for feedback based on user perception [5, 9, 13, 14, 15, 23].

Based on this idea, the Ergonomics Research Division at the Pontificia Bolivariana University's (UPB) Faculty of Design suggested setting up a seedbed research group to develop a research project whose general objective was to create a system that allowed a designer to simulate the individual functional states of a particular user. This would allow designers to better understand the user's listening, visual and motor characteristics, postural condition, and relationship with an environment conceived for the information gathering stage of the design process.

What strategies in the teaching-learning process could help students better understand the physical and cognitive characteristics of the user? Based on detailed analysis of design teaching methods and other fields, it was shown that "simulating" human activity was imperative. For the purposes of the project, "simulation" was defined as: "The process of designing a model of a real system and conducting experiments with this model to understand the behavior of the system" [22].

Project: "Bodies simulating the functional state of elderly adults"

Because of the growing number of elderly people in Colombia, it was decided that the user in this particular project would be an older adult. Indeed, by 2050, the number of people aged 60 years or over is expected to reach 15 million people, or about 24% of the total population [3, 21].

Moreover, there is evidence to suggest that mass-produced, everyday products and contemporary urban architectural spaces have been poorly adapted to meet the needs of people between the ages of 65 and 90. From a usability perspective, activities become inefficient, limited and prone to accidents that can be harmful to the user [3].

Designers have paid too little attention to this particular niche in the market, detaching themselves from a problem that is affecting communities both nationwide (where a "rise in the elderly population in Colombia is beginning to outpace the growth of younger generations," [7]) and at international level. Problems persist because products are designed under optimum conditions of use and earmarked for users without severe physical limitations, creating commercial rather than social designs.

Methodology

The following methodological process was used for the ERGO seedbed research process.

Selection of clinical conditions

As part of the research process, this stage consists of a series of activities using bibliographical references and expert opinion to examine how an elderly person is affected by conditions related to the aging process. Following a review of the information, medical conditions that could be simulated for each of the projects are selected.

State of the art knowledge

Alongside this enquiry process to select the medical conditions to be simulated for each of the projects, a “state of the art” study was carried out that identified a wide range of objects linked to the treatment and control of medical conditions. The study, which also identified objects used to simulate the functional state of an elderly person, aimed to gather relevant information that responded to the demands of each product.

Design Process

Following the research phase and the analysis of the problems faced by elderly people linked to postural and movement degeneration and the loss of hearing, sight and fine and gross motor skills, a series of design approaches were examined that responded to the objectives of each project.

Following on from this stage, relevant data from the project was brought together to determine the requirements of the functional-operative, technoproductive and esthetic-communicative components. During the design process, and based on the requirements of simulation, the different types of components, mechanisms, shapes and materials were established that would reproduce the selected medical conditions. This aimed to kick start the formal research process to establish early designs and models that would enable the development of a first validation and, subsequently, a second improved prototype.

Results of the project

Visual-Hearing Simulator

The objective was to develop an element that represented the different visual and hearing limitations linked to the ageing process. The research recognized four main age-related conditions that were earmarked for simulation: (i) cataracts, (ii) glaucoma, (iii) macular degeneration, and (iv) diabetic retinopathy. The following hearing disorders were also deemed to be prevalent among the elderly: (i) presbycusis, and (ii) tinnitus.

The simulator comprises a structure that supports a series of transparent screens. Polarizing film or laminate has been attached to the screens and digitally altered according to the characteristics defined by visual impairment at different stages of development. The simulator has an adjustable strap system to ensure a more comfortable fit, while the screens are prevented from coming in to direct contact with the face to ensure the structure remains hygienic (Fig. 2 and 3).



Fig. 2. Visual-hearing simulator concept

Source: student presentation – seedbed ERGO – UPB.

The hearing simulator is attached to the simulator structure to form a single system. The design comprises anatomical earmuffs and polymer material that can be adapted to fit the shape of the user's head and face. Three types of foam of varying density reduce high-pitched sounds (presbycusis) to generate three levels of external noise insulation. The simulation of tinnitus is conducted through earphones incorporated in to the interior part of the simulator. A Bluetooth connection links a sounds folder, which can be downloaded or reproduced using a website or mobile application (Fig. 3).



Fig. 3. Hearing application

Source: student presentation – seedbed ERGO – UPB.

Simulator of fine motor skills

The objective was to develop a glove that simulates fine motor skill limitations in the hand as a result of the ageing process. The simulated condition is rheumatoid arthritis, characterized by joint inflammation.

The glove was created using the elastic properties and vectorial force of the textile to generate a counterforce to hand movement. This enables applied exertion and movement precision to be reduced, simulating the loss of muscle mass. Reinforcement materials located in the phalangeal joints allow the glove to generate a compression force. This limit the range of flexion-extension movement during different grip positions of the hand, simulating the discomfort of arthritis (Fig. 4).



Fig. 4. Fine motor skills simulator concept

Source: student presentation – seedbed ERGO – UPB.

Posture-movement simulator

The objective was to develop a harness to recreate the posture and movement of an elderly person. The aim was to reveal the following features of biomechanical and postural change linked to the ageing process: (i) the increase in the curvature of the upper back (kyphosis), (ii) the lateral curvature (left or right) of the spine (scoliosis), and (iii) the exaggerated curvature of the lumbar zone (lordosis) [2].

The harness system employs an adjustable strap mechanism that tilts the back for-forwards at different degrees depending on the level of curvature required, thus enabling the user to adopt the required posture. Tension control of the strap mechanism also allows the user's body to tilt sideways, enabling a sideways movement of the back. The posture system's strap mechanism is connected to the movement simulator, which in turn is fitted to the user's knee. Flexion-extension movement is restricted in a controlled manner through tensors (thera tubes) that possess varying degrees of elasticity. The two systems are brought together to reduce stride length and walking speed thus effectively recreating the biomechanics of an elderly person (Fig. 5).



Fig. 5. Posture and movement simulator concept
Source: student presentation – seedbed ERGO – UPB.

Conclusions

The use of “simulation” as a pedagogic strategy in the process of design allows the designer or student to: (i) demonstrate what has been learnt in the research and problem definition stages, translated into design inputs, thus reacting in advance of what may happen in a real context, (ii) obtain accurate data during the exercise, (iii) define the User-Context-Object system under analysis, based on the designer’s experience and perception of the situation that simulates reality, (iv) develop clearer understanding of the activity’s objectives, (v) replicate the experience, (vi) standardize the process, (vii) implement the teaching exercises, (viii) evaluate criteria related to reality, (ix) establish evaluation criteria, (x) develop a wider range that is more representative of the problems, according to the particular design case, (xi) ascertain student performance.

Despite this, it is important to clarify that simulation is still only a technique that simulates reality. An exact reproduction of people’s lives and behavior is difficult, and represents the concept’s biggest limitation. Caution is therefore advised when predicting a situation based on the findings of simulation. It is important to recognize that an individual may react differently to a real-life situation; therefore simulation alone is insufficient when attempting to understand a real context or user. Subsequent tests must be carried out to determine if the information gathered

during the simulation phase is accurate, and if the exercise can be repeated for different individuals with the same profile.

The scope of the project is earmarked for academic use and implemented in UPB's ergonomics laboratory, which is always striving towards improving the learning process of Industrial Design students. In addition to the prototypes, a guide and user manual has been developed for elderly people to complement the usability of the design objects.

Acknowledgements

We would like to thanks the students and professors who participated in the implementation of this project: Daniela Díaz Mejía, Mathieu Harpert Correa, Sebastián Rodríguez Gómez, Cristian Camilo Ramírez Martínez, Sofia Buitrago Ángel, Daniela Bedoya Llano, Diana Marcela Restrepo, Cristian Nazar Soto, María Elisa Oquendo Flórez, Ana Catalina Valencia, Ángela María Echeverri Jaramillo y Alexander Cardo-na Galeano.

References

- [1] **Bradley, P.T.:** The history of simulation in medical education and possible future directions. Medical Education (2006)
- [2] **Cerda, L.:** Manejo del trastorno de marcha del adulto mayor. Instituto Nacional de Artritis y Enfermedades Musculoesqueléticas y de la Piel. (15 de 3 de 2010), 2014.
- [3] **Concha, F.S.:** Fundación Saldarriaga Concha. Retrieved Enero de 2017 from COLOMBIA, UN PAÍS QUE ENVEJECE DE MANERA ACELERADA: <http://www.saldarriagaconcha.org/es/prensa/noticias/item/577-colombia-un-pais-que-envejece-de-manera-acelerada>, 2015.
- [4] **Córdova, C.P.:** La simulación como apoyo didáctico. Académico de la Facultad de Ingeniería B. U. A. P. 2010.
- [5] **Coss, R.:** The Role of Evolved Perceptual Biases in Art and Design. Evolutionary Aesthetics. E. Volland and K. Grammer, Springer Berlin Heidelberg, 2003, 69-130.
- [6] **Diker, G., & Terigi, F.:** La formación de maestros y profesores: hoja de ruta. Paidós 1997.
- [7] **EL TIEMPO** (4 de Octubre de 2015). El Tiempo. Recuperado el Noviembre de 2016, de Colombia dejará de ser joven en el 2020 - En el 2050, el 21 por ciento de los mayores superará los 80 años. Ciudades pobres, las más jóvenes, <http://www.eltiempo.com/archivo/documento/CMS-16394192>, 2015.
- [8] **Fingermann, H.:** La guía. Retrieved 9 de 06 de 2016 from Educación – Técnicas de simulación: <http://educacion.laguia2000.com/estrategias-didacticas/tecnica-de-simulacion> 2010.
- [9] **French, M.:** Engineering design: the conceptual stage, 1971, Heinemann, London 1985.
- [10] **Litwin, E.:** El oficio de enseñar. Condiciones y contextos. Buenos Aires: Paidos 2008, 102-103.

- [11] **Medical, L.:** Laerdal helping save lifes. Retrieved Enero de 2017 from Resusci Anne Simulator El simulador de RCP polivalente, <http://www.laerdal.com/la/doc/75/Resusci-Anne-Simulator>, 2017.
- [12] **Monterrey, I.T.:** Centro de investigación de técnicas didácticas. From http://sitios.itesm.mx/va/dide2/tecnicas_didacticas/simulacion.htm, 2010.
- [13] **Moultrie, J., Clarkson, P.J. and Probert, D.:** A tool to evaluate design performance in SMEs. *International Journal of Productivity and Performance Management* 55(3/4), 2006, 184-216.
- [14] **Nelson, J., Buisine, S. and Aoussat, A.:** Anticipating the use of future things: Towards a framework for prospective use analysis in innovation design projects. *Applied ergonomics* 44(6), 2013, 948-956.
- [15] **Pedro, R., Mondelo, E.G., Pedro, B.:** *Ergonomía 1 Fundamentos*. Barcelona, CPDA 1999.
- [16] **Perea, R.S., & Zulueta, P.A.:** La simulación como método de enseñanza y aprendizaje. C.N. Enseñanza (Ed.) *Rev Cubana Educación Médica Superior* 1995.
- [17] **Preciado, S.A.:** La Simulación como estrategia didáctica en medicina interna. Instituto Nacional de Cancerología – E.S.E. 2010.
- [18] **Ruiz, J.:** La simulación como Instrumento de Aprendizaje. Evaluación de Herramientas y estrategias de aplicación en el aula 1998.
- [19] **Sánchez, M.M.:** La simulación como estrategia didáctica: aportes y reflexiones de una experiencia en el nivel superior (U. N.-F.-D. Trelew-Chubut, Ed.) 12 (1853-9424) 2013.
- [20] Scientific 3. 3B SCIENTIFIC. Retrieved 2017 de Enero from SiMone Simulador de nacimiento, https://www.a3bs.com/simone-simulador-de-nacimiento-p801,p_895_27376.html, 2017.
- [21] **Semana:** Retrieved Enero de 2017 from Colombia envejece a pasos acelerados Para el 2050 cerca del 24% de la población tendrá más de 60 años. Los grandes desafíos son aumentar los gastos para protección en salud y pension, <http://www.semana.com/nacion/articulo/colombia-envejece-pasos-acelerados/444211-3>, 2015.
- [22] **Shannon, Robert E.:** Introduction to simulation. In *Proceedings of the 24th conference on Winter simulation*, ACM 1992, 65-73.
- [23] **Stanton, N. and Young, M.:** Is utility in the mind of the beholder? A study of ergonomics methods. *Applied Ergonomics* 29(1), 1998, 41-54.

THE CONCEPT OF THE FUND FOR THE DEVELOPMENT OF SMART CITIES (FDSC)

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Abstract: This study is focused on the problems and development opportunities of two topics: the concept of Smart City, and solutions that help blind people in their everyday life. The study analyses the existing solutions aiming to help visually impaired people. The result of the analysis shows that many of the functions are repeated in the applications and there are no applications that would provide a comprehensive solution for blind people's everyday life problems. The author proposes a new direction for development in some points for both Smart Cities and solutions assisting blind people. A proposed organization, the Fund for the Development of Smart Cities (FDSC) – that may help to ensure the financial background of the R&D, and also could set a centralized direction for development worldwide –, the usage of Open data and Open software development concepts, the technology of artificial Intelligence (AI), and autonomous cars.

Keywords: Smart City, visually impaired people, development.

Introduction

Currently, 54% of the world's population is living in cities, while fifty years ago it was only 36%. This number is expected to be around 66% by 2050 [4]. This rapid urbanization creates a major challenge for today's governments. The maintenance of the infrastructure, or ensuring frictionless urban mobility, food, water and energy supplies, and waste management are getting more and more difficult.

One of the main concepts that aim to find new solutions for the aforementioned problems is the idea of Smart City. It is a popular topic that, some decades ago, may seem utopic, but until now, the rapid pace of the technology advancement, the development of ICT (Information and Communication Technology) and IoT (Internet of Things) have made it a realistic idea. The cities of developed counties are competing, of which some of them can be named as the World's Smartest City. However, some of them prefer to use livable city expression not forgetting that the most important for them are the residents. The main aim is to improve the quality of life in the cities, but since

there are vast differences between one citizen and another, it is also intended to balance the inequality.

The disparity in the way of living is particularly valid for people with disability. The poverty among this group of society is usual, because often they are unable to work due to their disabilities. Moreover, most of the everyday activities mean difficulty to them. One of the most populous group within the disabled are visually impaired people who have to live without the most important human ability, vision. The development of information technology and the Smart City concept offer a unique opportunity for the blind to have less difficult life.

Since the topics “Smart City concept and the urban life of the blind” are linked by many strands, it seems reasonable to create analysis of both, and propose development plan for their solution.

Analysis

The author has made a non-comprehensive analysis of the already existing systems and solutions supporting blind people. Figure 1 shows the duplicated functions of the analyzed 30 solutions.

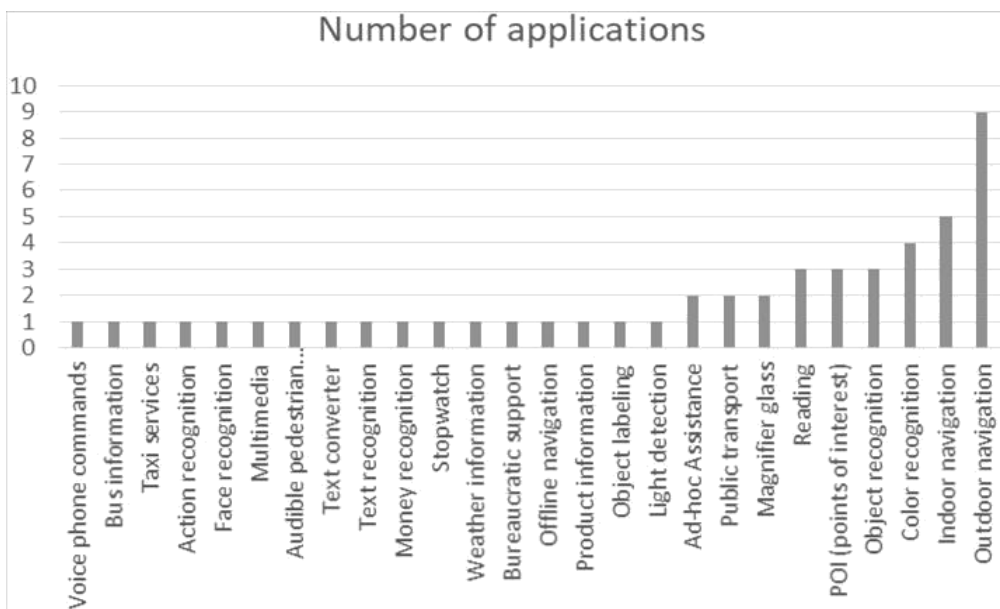


Fig. 1. The number of occurrence of functions within the solutions

Source: own work.

It can be observed that 37% of all the collected functions are included in more than one applications or systems. From one side, it is positive that the developers are trying to create customized solutions for different countries or

regions; on the other hand, this is not cost effective, and by centralizing the work and resources, it would be possible to make much more sophisticated and more agile applications and systems. However, from the observations, it can be also concluded that there is no application available on the market, which would offer comprehensive solution for the blind.

Development propositions – integration, cooperation

The analysis shows clearly that there is a need for development in the topic of solutions supporting the blind. The author tends to list and describe suggestions for future enhancements that are universally applicable for both the problems of urbanization and the blind community, since they are connected with each other in many ways.

Research and development can be considered as a very important element of the economic growth, therefore these innovative recommendations are not just beneficiary directly in their field, but also contribute to the world economy [9].

Fund for the development of Smart Cities (FDSC)

The development of the Smart City concept is the interest of the whole world. It is the idea that might enable the humanity to create a sustainable future. Since the population of the world is rapidly increasing, the implementation of smart solutions in cities sooner or later will be inevitable. Similarly, the support of the blind must be considered in all major countries in their social governance policies. There are many existing solutions supporting blind people and certainly more will be invented and released to the public; however, it is clearly visible that the current ways of development are ineffective. There are many solutions developed in various applications, but often these ideas are not well implemented into practice.

Therefore, instead of the current decentralized structure, the establishment of a common development fund is suggested that would assign grants to inventors, groups of developers, and coordinate development through a centralized strategy. As a result, a team would work together on one functionality, and the solution could be much more sophisticated than in the case when more teams work independently from each other.

Just like in corporations, international virtual teams can be set up, so that specialists from every corner of the world may be involved in the development process of projects. The Fund could bring together scientists to work on a common project to create a better, more efficient future. These diverse teams would be able to work cost-effectively and obtain more sophisticated solutions: instead of rivalry, the focus would be on the product.

Since the work will be conducted throughout the world, one of the main challenges for managers will be the formalization. "Formalization is the

formulation of principles, rules and norms, which are binding and regulates the functioning of an organization” [8]. This will ensure the mutual cooperation between the team members and the departments, as well.

The organizational structure of the Fund is going to consist of three basic levels of management: top (board of directors), middle (department), and first-line managers [1].

The Fund is to be led by an international board of directors. They will keep contact with the representatives of all the partner countries. In cooperation with these countries, they will be responsible for defining the basic principles, mission, vision, and strategy of the Development Fund, and setting a clear direction of the investments.

The organization will consist of five departments: Health, Infrastructure, Mobility, Public and Social Services, and Security. The Health department is responsible for the modernization and digitalization of healthcare data, and simultaneously for the development of state-of-the-art solutions in order to obtain better cost-efficiency in the sector. The Infrastructure department will focus on smart solutions of waste, energy management, and smart grids. The Mobility department aims to develop the management of urban public transport, traffic management, and comprehensive software for navigation supporting disabled and non-disabled people, as well. The Public and Social Services department will be responsible for the improvement of online public services, smart social initiatives, and also for smart home solutions. The Security department will focus on crime prevention and citizen protection solutions using state-of-the-art technologies.

All departments will report to the board of directors on a monthly basis. In each organizational unit, selection committees will be elected that will be responsible for deciding which projects will grant by the organization. In case of complex interdepartmental projects, for decision, special committees will be set up by the board of directors. This committee will have members representing all involved departments. In each case, the committee will decide on the proposed projects whether or not they are aligned with the Fund’s defined development goals and strategy.

The work of the departments will include:

1. Defining the formal requirements of the application for grant and informing the public about them.
2. Providing support for potential or actual applicants about the application process.
3. Popularizing the organization and its initiatives.
4. Collecting and assessing applications.
5. Providing information and templates for reporting.
6. Cooperating with other departments in case of interdepartmental projects.
7. Making bank transfers to the organization that have been granted.
8. Making accounts, reviewing the spending of projects.

Since the more complex and larger projects are going to be cross-functional, it is intended that the project work and the cooperation between the departments would be coordinated by project managers.

The architecture of the proposed Development Fund is illustrated in Figure 2 in three dimensions: strategic aspect, department and geographical location. To give a visual overview of the Fund's work, four projects are placed on the figure as examples. Strategic approach means the principle that is involved in the given project, namely the promotion of open data or the open software development concepts, innovation, and equal opportunity. The latter focuses on minimizing the obstacles for disabled people, so they could live with equal opportunities in the cities of the future.

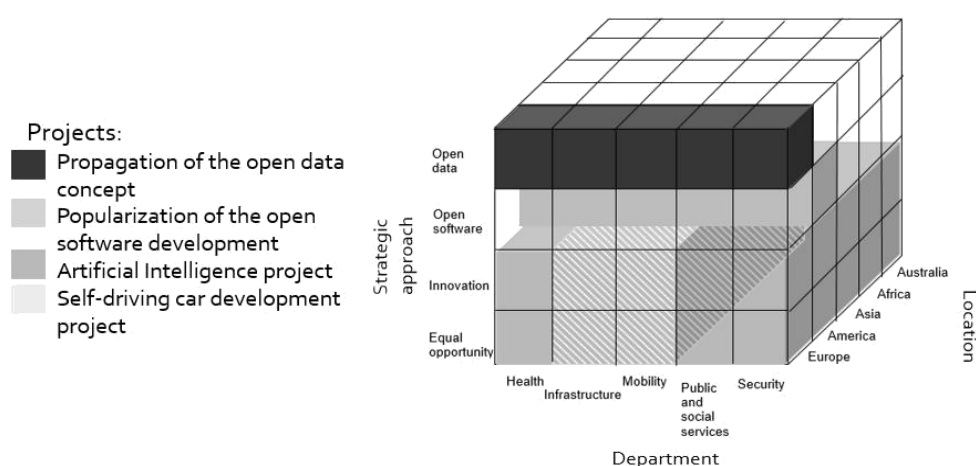


Fig. 2. The architecture of the fund for the development of Smart Cities
Source: own work.

Two projects from the four are directly related to the Equal opportunity approach: Artificial intelligence project and the self-driving car project.

The Artificial Intelligence project will be carried out worldwide (in international virtual teams), since there are already ongoing research and development works by various companies in different locations. These works will be united according to the plans as a part of strategic alliance. The project concerns the Innovation strategic approach, since the new technology that can be created as the main product would mean a revolutionary innovation in people's life. This innovation would also provide benefits to issues concerned by all the five departments, therefore it is planned to be co-financed and coordinated by them.

The last pre-defined project is the worldwide development of the self-driving car and other services related to it, such as the autonomous taxi service. Similarly to the artificial intelligence project, it is planned to be coordinated worldwide, because there are already ongoing development projects throughout the world. The work will be carried out according to two of the strategic approaches: innovation and equal opportunity. The latter is involved, since the

product of the project will ease the life of disabled people – especially for the blind. It will be financed and coordinated by two departments, mobility and infrastructure, because this solution will make fundamental changes in both the mobility of the citizens, and the infrastructural conditions, for instance energy requirements will decrease due to the optimized driving style of the autonomous cars.

Open data

A principal that should be applied in the projects of the Development Fund – to facilitate the progress of the Smart City concept and the blind supporting solutions – is the open data. It is already used by the municipalities of New York City and the European Union; however, in order to exploit all its benefits, it should become a worldwide practice. Sharing data and knowledge is generally a fundamental element of the development, but when we are talking about technology related topics, it is exponentially important.

“Open (Government) data refers to the information collected, produced or paid for by the public bodies (also referred to as Public Sector Information) and made freely available for re-use for any purpose. The license will specify the terms of use [...].

[...] Public sector information is information held by the public sector. The directive on the re-use of public sector information provides a common legal framework for a European market for government-held data. It is built around the key pillars of the internal market: free flow of data, transparency and fair competition. It is important to note that not all of the public sector information is Open Data” [2].

Open data has various benefits that range from social welfare to the boosted economic growth of the private sector, and higher efficiency of public services and administration. The economy may benefit by accessing easier knowledge, information and content, so innovative services, and new business models can be created much quicker and cheaper. Public services may be more efficient and a cost overview can be obtained by cross-sector data sharing to see where unnecessary spending appears in the system.

Data sharing opens new opportunities for software development: different systems can be integrated and leverage from each other’s functions or data. For instance, the traffic data measured and collected by the government, or points of interest information from data base of other systems may be used for optimizing the operation of navigation software. The variety of possible ways of cooperation like these is countless, it only depends on the willingness of the market participants.

Although there is a European Union-funded organization that aims to promote the open data concept and harvest the public sector data from public data portals of European Union countries, it is needed to make open data well known within the society and create a cooperation in a wider perspective than the European Union.

Open software development

After opening data, the next thing to be applied in the Development Fund's work is to increase the number of open-source software. "Open source software is one with a source code that anyone can inspect, modify, and enhance.

"Source code" is the part of software that most computer users are yet to see; it is the code that computer programmers can manipulate to change how a piece of software – a "program" or "application" – works. Programmers who have access to a computer program's source code can improve that program by adding features to it or fixing parts that do not always work correctly" [6].

When the code of the existing smartphone application solutions in the two topics analyzed in the study becomes available to other software developers, it is going to cause a massive progress in these fields. The only question is if people will be able to realize that some topics should be considered not exclusively according to profit, but the public interest and assistance of the handicapped are to be prioritized.

The ultimate goal in the topic of solutions supporting blind people would be to integrate the existing applications into one. If it happens, the blind will be able to just use one default application on their smart devices. In this case, they would not have to open up several different applications and it would be easier for the devices as well to handle one running application only. Currently, most of the applications are available for integration exclusively if the other party purchases licenses. If the application owners agree on the open software development, this objective will be finally within reach.

The Development Fund mentioned in this study, under the topic Fund for the Development of Smart Cities (FDSC), should be able to compensate partly the loss of some market participants (application developers) who are willing to share their code.

Artificial intelligence

The currently existing so-called artificial intelligence (AI) systems are basically advanced machine learning software equipped with large-scale behavioral algorithms, which can adapt their operation to the users' preferences. Although they are acutely useful, these machines are not able to get smarter in the existential sense, but they can improve their accuracy and skills by executing analyses of a large dataset.

There are various applications of artificial intelligence, some of them are applied in the solutions discussed in the analysis part of the study e.g. public transport planning or traffic management in Smart Cities, and the face, color, object recognition of the Aipoly mobile application.

However, the artificial intelligence has begun to propagate in this field, there are obviously huge opportunities for further improvement. There are four main

areas of AI application currently: speech recognition, machine learning, robotics, and expert systems [5].

Expert systems are AI-powered computers that are able to receive and process data much quicker than human workers. For example, IBM's Watson can diagnose cancer with nearly 90% accuracy, while experienced doctors only with 50%.

Speech recognition is well known in the industry, and is used by some of the analyzed applications for the blind or they use the built-in iOS or Android functions. But the most sophisticated solutions of speech recognition are Apple's personal assistant software, Siri and Amazon's voice-controlled smart home hub, Alexa [7].

Google is currently using artificial intelligence for machine learning in its search applications. This service, which is equipped with machine learning algorithms, provides users with more relevant content than ever, therefore it makes slowly the traditional search engine optimization techniques less and less competitive on the market.

Artificial intelligence can be applied in two kinds of robotics: physically existing robots can be applied in different fields, such as agriculture or manufacturing. An example for this is a Japanese company [3] producing lettuce that plans to use robots to harvest plants. The other kind of robotics is the business process automation or robotic process automation. These robots do not have hardware, but with software that can be taught to execute those repetitive processes which are too monotonous for human workers, ergo can be much more effective and faster.

Artificial intelligence can be a key element in state-of-the-art solutions for helping blind people. Many existing ways of its application can be combined in order to achieve a great product. Alexa, Amazon's smart home product can be integrated with some other visual sensors and smart home devices around a blind person's flat to assist him or her in everyday home activities.

Furthermore, a similar solution to Apple's Siri could be used in autonomous cars that provide taxi services among blind people as a personal assistant that keeps contact with the passenger during the whole ride. The detailed development proposition of this solution is described below.

Self-driving car

Autonomous cars are currently being tested by various companies (for example Tesla, Uber) and even self-driving mini buses are operating on the streets of Tallinn, Estonia. This shows that sooner a new era will begin in mobility. Bus, taxi, and truck drivers will be replaced by robots, and agricultural machines are going to be automatized, as well. Currently, all projects that are in pilot phase received permission to use the autonomous cars only with a human backup driver, who can take over control in case of emergency.

When the technology will be ready, more and more self-driving vehicles are going to travel on the roads and this will reduce travel times, the occurrence of traffic jams, and CO₂ emission and improve safety on the roads.

The mobility of the blind could be changed extremely by the introduction of self-driving cars. First of all, simple things like crossing a road would become safer for them as self-driving cars pay attention on pedestrians better than human drivers. Furthermore, by combining autonomous cars and artificial intelligence software, such as Apple's Siri, and Uber's taxi services, a model of self-driving taxi service could be created that would make a new chapter in blind people's mobility.

The process of taking the autonomous taxi service for blind people is the following: The visually impaired person having a demand for a ride opens up the application that provides self-driving taxi services. This application can be controlled fully by voice commands and keeps contact constantly with the user. Firstly, the passenger is able to choose the company according to his or her brand preferences. This prioritization subsequently helps the application to propose other solutions for the customer.

Then, the customer gives the destination address and the time he or she wants to start the journey (demand information). This data is being stored in the company database for further analysis of the demand.

After this, the application sends the request to the taxi service provider's system where the car availability is being checked. At this point, there are two scenarios that can happen: either a car is available, so that the service provider accepts the request, or it is refused due to car unavailability. In case of a refused request, the passenger can also decide whether he/she changes the travel and demand information or chooses another autonomous taxi service provider.

When the request has been accepted, the passenger has opportunity to negotiate the travel conditions, such as travel time, comfort category (type of taxi), and cost. The application sends the customer's proposal to the system and the service provider decides whether the conditions are accepted or not. If the proposal is refused, the passenger can either renegotiate the conditions or choose another company from the offer.

When the proposal is accepted, the official order is being made and the taxi provider initiates the ride by commanding the self-driving car a pick-up. It is important to highlight that the entire ordering process is conducted as a continuous verbal communication between the blind passenger and a robot of the taxi service application that is equipped with an artificial intelligence machine and is in a constant contact with the taxi service providers and the self-driving car.

The ride is initiated when the blind passenger submits the official order for the travel. The self-driving car picks him or her up on a place where traffic rules and parking opportunities make it possible. The application ensures that the visually impaired customer is being navigated (by verbal communication) to the exact place the taxi parks down. When the ride starts, the passenger remains in direct contact with a robot. This bilateral communication ensures that the blind

person is provided with comfort and the service provider earns his or her trust during the travel.

Close to the end of the journey, the passenger is invited to submit a customer service questionnaire that can help the service provider in future improvements.

Similarly to the pick-up activity, at the end, the self-driving car seeks for a safe parking spot near the place of requested destination. After the arrival, the blind passenger sends the confirmation of service to the taxi company through the application.

After the order is made successfully, the self-driving car picks up the passenger and transports him or her to the desired destination. Obviously, during the ride, the self-driving car's software considers the general traffic rules and safety regulations very strictly. At the arrival, the customer's demand is satisfied and he or she acknowledges in the system that the ride has been accomplished.

The next step of the process is the payment. The passenger is redirected to the payment platform where the transaction is being made between the blind person's bank and the taxi service provider. Just as previously, the visually impaired customer is able to confirm the payment in voice commands.

The process is being finalized with the invoicing to the passenger. The invoice is automatically issued by a third-party accounting service provider (aligning all local tax regulations) and the documents are being archived in an invoice database.

Conclusion

In addressing the problem of the urbanization and visually impaired people, it is suggested to establish the Fund for the Development of Smart City. It would be able to create a managed environment and a financial base for the development of comprehensive solutions for the blind. Implementing the main principles (open data, open software development, artificial intelligence, self-driving car), revolutionary solutions could be developed by international virtual teams. For instance, a fully automated self-driving taxi service could be created that would be able to bring vast changes in blind people's mobility.

References

- [1] **Griffin, R.W.:** Management, Cengage Learning. 10, 2010.
- [2] <http://data.europa.eu/euodp/en/data/> – European Open Data Portal – accessed on 27.08.2017.
- [3] <http://spread.co.jp/en/technology/> – accessed on 27.08.2017.
- [4] <https://esa.un.org/unpd/wup/publications/files/wup2014-highlights.Pdf> - World Urbanization Prospects – accessed on 28.08.2017.
- [5] <https://medium.com/@andrei.klubnikin88/top-4-applications-of-artificial-intelligence-in-business-7804e3cf9bf0> - Top 4 Applications of Artificial Intelligence in Business, Medium – accessed on 30.07.2017

- [6] <https://opensource.com/resources/what-open-source> – accessed on 30.07.2017
- [7] <https://www.forbes.com/sites/robertadams/2017/01/10/10-powerful-examples-of-artificial-intelligence-in-use-today/2/#38bd44683c8b> – accessed on 30.07.2017.
- [8] **Kozminski, A.K., Jemielniak, D.:** New Principles of Management, Peter Lang, Frankfurt am Main 2013.
- [9] **Marciniak, S., Wiszniewski, W., Głodziński, E.:** Zarządzanie innowacjami a cykle gospodarcze. Wyzwania, relacje, metody, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2015.

HUMAN FACTOR DESIGN
FOR BARRIERS REDUCTION

LANGUAGE MEDIATION AS AN AREA OF RISK FOR A DEAF PERSON

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Abstract: The article presents the risk areas of dependence in communication of persons with disabilities. In particular, it describes interference with communication and social relations of deaf persons and their sign language interpreters. Based on long-term observations and 25 autobiographies of deaf/hard-of-hearing students, seven major risk areas were identified and described: 1) risk of intentional or unintentional meaning distortion, 2) risk of mediator's dominance in the process of communication, 3) risk of initiating communication only in presence or through mediator, 4) risk of a "social filter", 5) risk of "protective umbrella" and isolation, 6) risk of the instrumental relations and 7) risk of excessive attachment – personal dependency.

Keywords: sign language, disability, communication, dependence, language mediator.

Introduction

The sign language interpreter's support is a basic form of compensation for the limited ability of the deaf to communicate with hearing people. He is also treated in terms of the right of disabled people to freely use the form of communication he or she chooses, but also to take advantage of help from chosen person when it comes to contact with obliged entities. Art. 21 of Convention on the Rights of Persons with Disabilities (CRPD), obliges States Parties to "accepting and facilitating the use of sign languages, Braille, augmentative and alternative communication, and all other accessible means, modes and formats of communication of their choice by persons with disabilities in official interactions" [4].

Engaging a sign language interpreter is currently treated in most countries as an obvious social service. It can be perceived as a form of situational intervention, eg. for health services, in office, in criminal justice situation [10], but often takes the form of long-term interpreter's assistance, related to education or work by the deaf. There are more and more such cases.

Contemporary literature forms the theoretical foundations of the translating/interpreting process, useful in the education of interpreters, such as sign language interpreters. Monikowski and Winston [12] describe two major models of interpreting which have had significant impact in this field: 1) Colonomos's

integrated pedagogical model, 2) Cokely's model of overall interpreting process (Table 1).

Table 1. The main models of interpreting of sign language

Author	Type of interpreting model	The main aspect/steps of interpreting process
Betty Colonomos 1992	The integrated model – pedagogical	• C – concentrating on the source message • R – representing the meaning • P – planning the target text
Dennis Cokely 1992	The process model – sociolinguistic	• message reception • preliminary processing • short-term message retention • semantic intent realization • semantic equivalence determination • syntactic message formulation • message production

Source: own elaboration based on [13].

Translation models, similar to those in the Table 1, may be useful in developing translators' skills and play an important role in their vocational education. There are also other interesting concepts of interpreting – see Taylor, Seleskovitch, Metzger, Wadensjo or Roy [11, 13, 19] – however, they do not analyse the social and personal consequences of long-term deaf's dependence (and in general – persons' with disabilities dependence) on language mediator. The reflection on the potential threats associated with such situations is unfortunately rarely observed. The interpreter gives deaf people an opportunity to contact with the world and to achieve their life goals. On the other hand, there is a risk of interference with social relationships, including the threat of a new kind of dependency: the dependency from linguistic mediator [18]. Von Tetzchner and Martinsen, who deal with alternative and supportive communication (AAC) issues, validate concerns about an excessive dependence of people with disabilities on communication support [21]. Following the research, the author of this paper synthesized her own experiences gathered during her many years of academic work with deaf students to identify the threats to which deaf people are exposed as well as their interpersonal relationships arising from the long-term support of a sign language interpreter.

Research objective and methodology

The purpose of the research was to identify threats to the deaf person and his or her interpersonal relationships, which occur in the situation of a long-term support by a sign language interpreter. The research is based on a constructivist paradigm. The basis of analysis were the 9-year observations made by the author – psychologists, special educators, academic spokesperson of students with disabilities and tutor of deaf students at the Pedagogical Academy (WSP) in Lodz [17]. More than 60 deaf and hard-of-hearing have studied there in 2004-2012.

For their needs, Pedagogical Academy employed seven sign language interpreters hired under the “Pitagoras” program founded by the State Fund for Rehabilitation of the Disabled (PFRON).

Observations were collected in the course of daily work with students and their interpreters, while resolving problems and interventions. This was a form of action research, which allows for linking theory with practice and specific activities with scientific exploration. *Action research* is a form of studies on the social situation in which the researcher is located, with the intention of improving it. As an inspirer and active participant of events, the researcher makes some changes, but also systematically collects information about perceived and investigated phenomena [5]. At the same time, created situation made it possible to make systematic observations, consisting of the further presented generalizations, grounded in the observations (*grounded theory*) and supplemented by a review of literature [3]. A part of the corpus also comprises 25 in-depth narrative autobiographies of deaf students – 18 women and 7 men aged 23-28. Each of them knew the sign language (mainly PJM), all used interpreters. Only a few people were able to effectively communicate orally. Persons with deep pre-bladder deafness (N = 15), 16 people declared themselves as a (culture) Deaf, 6 as hard-of-hearing, but related to Deaf Culture [10]. For 3 students such a categorization had no meaning. Detailed characteristics of this group are presented in the other author’s monograph [17].

Research results

Attempts of regulating various situations observed between interpreters and deaf students lead to the seven risk areas which I will discuss in separate section: 1) risk of intentional or unintentional meaning distortion, 2) risk of mediator’s dominance in the process of communication, 3) risk of initiating communication only in presence or through mediator, 4) risk of a “social filter”, 5) risk of “protective umbrella” and isolation, 6) risk of the instrumental relations and 7) risk of personal dependency.

Risk of meaning distortion

The risk of meaning distortion is connected with the dependency from competences and intentions of a mediator. Mediators are usually parents or close relatives who accompany the child in a natural way. The choice of a therapist, a teacher or an interpreter is usually chosen by accident in a random way. In WSP some interpreters were bilingual using Language-Sign System (SJM) and natural Polish Sign Language (PJM). There were situations of matching an interpreter to a particular student or a group as well as restrictions to such matching. It is important to stress that an interpreter who matches some students

does not have to necessarily match others. Such situation should be treated as normal – but is not.

When using a help from an interpreter, supported persons are not able to confront the transmission with an original text, they are at the mercy of an interpreter, they cannot identify the source of potential disturbances of communication process: whether it is a sender or a mediator. The problem may only be solved by a control and certification of the work of interpreters with simultaneous care about their high ethical level and the feeling of responsibility. In numerous countries the process of vesting translation and teaching as well as alternative teaching or supporting communication means certifications are formalized for example in Poland, inter alia, Pictograms, Makaton, Bliss system, Fonogesty (Polish version of Cued Speech) or Sign Language (PJM, SJM). Similar systems are in other countries [14]. The certification system is a sign of responsibility for the quality and standardization of communication methods.

It is important to add that while preparing various groups of language mediators (e.g. interpreters or sign language teachers) also the introduction of various professional ethic codes with rules regulating certain behaviors and reactions towards taught people is included. One of the examples may be the Ethic Code of the Polish Sign Language Interpreters Association. The code includes the following areas of regulation: professional secret, professionalism, professional development, impartiality, respect to the sides of a translation, respect to other interpreters [9]. In the analyzed aspect of a translation especially important seem to be the rules on professionalism and professional development. The professional requirements are defined by a general rule that “a translator or an interpreter has professional and practical abilities as well as specialist and substantial knowledge about the deaf people’s environment necessary to conduct a translation” [9]. Following the rules in a reliable way increases communication security of a person with disability forced to use language mediation.

Risk of mediator’s dominance in the process of communication

In supported communication, an interpreter has a primary role in terms of communication efficiency and marginal role in terms of the real contact of both sides of a translation. It is very difficult to maintain balance between the two roles. Sometimes it seems that the role of a mediator is bigger than it actually is. The activity of an interpreter is naturally greater than any of the sides’. They repeat and sums up the utterances of both sides. That is why minimalizing their personal dominance may be difficult. It is also a craft proving high professional qualifications [10, 13].

When accepting the meaning of an interpreter and sides contacting through him it is worth underlining that there is a difference between focusing on the craft of translation itself and the interactive setup creating between the participants of this specific act of communication. The first aspect is rather connected with translation studies and the latter – social psychology of

interpersonal communication. Translation studies as a science about translations uses a term of translatorial setup (Fig. 1).

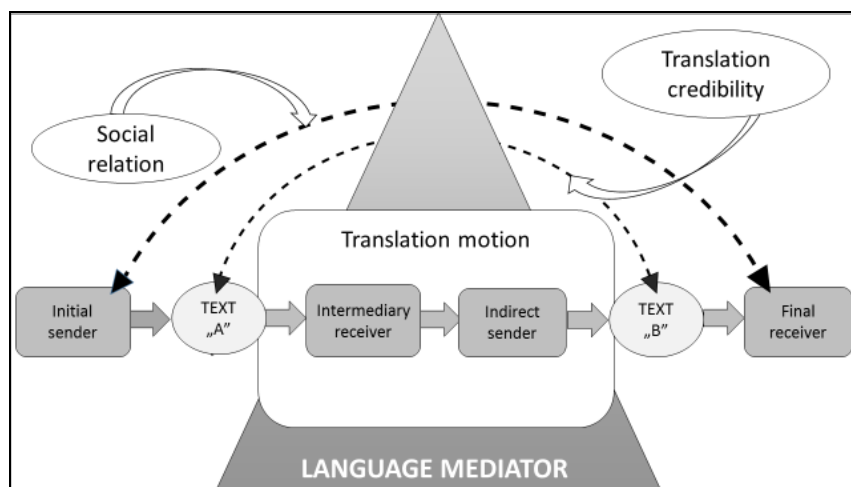


Fig. 1. Translatorial setup in case of communication with a usage of language mediator
Source: own elaboration based on [15, 16].

The Fig. 1 – inspired by classical translativ theory of equivalence of Nida [15, 16] – focus on the interpreter, and secondly on texts whereas both a sender initiating the content, and the final receiver are in the last place. But it is not a suggest of primary role of an interpreter and secondary roles of the sides of a translation. Within translation studies, the mechanisms of switching languages in a brain of an interpreter are the most important. The mechanisms are the subject of shaping various professional competences. This is a thing that must be learned by each interpreter. A communication phenomenon is that a translator/interpreter is both a sender (indirect) and a receiver (indirect). The credibility of the translation results from the consistency of text A and text B, which is the result of not only formal equivalence, but also dynamic. According to referred rules of translation studies, a text as a macro-sign conveys different meanings and it may replace subjective knowledge of an interpreter. There are texts which can be translated and interpreted on a basis of the knowledge coming from them. Nonetheless, it cannot be argued that also a non-language knowledge of an interpreter about translations decides about the understanding of a text. Only when a text “do not speak for itself”, it must be decoded and it must be given a certain meaning, an interpreter must find a particular context of the utterance – cultural and situational – and particular intentions of a sender and premises of understanding the text by a receiver [15, 16]. Obviously, there is no such an easy division on text with and without a context – a discursive character of a text always points at SOME personal, situational or historical context. That is why the broader the subjective and objective knowledge of an interpreter and experiences connected with cultures and environments of the users of both

languages are – the more adequate the translation becomes. It is also important in the case of communication mediation for people with disability. It is easy to notice that the more disturbed, incomplete and ambiguous the text of the initial sender is, the more important context factors are and the more attention should be paid to the persons of sender and receiver. It happens often with a translation for people with disabilities or translation of their distorted utterances. This points to the importance not only of linguistic, but also cognitive, technical [10], intra- and interpersonal skills of interpreter.

A translator/interpreter who works with disabled people with major communication disorders usually do not have a full text but only its distorted fragments, clippings, parts. Apart from the literal translation, there are many other detailed translation techniques, among others: free translation, chaining, sandwiching, chunking/bridging, codeswitching, translanguaging and other [10]. Interpreters can use suppositions and evaluate intentions directing themselves towards the sides of a translation and the situation they are into. Loeb1 describes a work with people with profound disability, as follows: *In education supporting* “the process of shaping communication abilities it is important that professionals do not focus only on realizable and instrumental aspects (methods, means and helps) but also that they have an ability to interpret unusual communication situations and behaviors of a partner. Furthermore, the belief about the necessity of creative and unconventional usage of various means, communication support and treating communication interaction as a meeting is very important. The condition for experiencing a meeting is understanding the way a child with disturbed development perceives the reality, what it feels and how it perceives our presence as a partner” [12]. In the most difficult communication cases, more often than in regular translation, intentions are – sometimes repeatedly – confirmed, meanings verified and fragmentary utterances or even single non-verbal signals and signs developed. In such situations we observe an especially distinct dominance of an activity and initiative of a language mediator and a great personal dependence of a person with disability from their presence. In extreme cases disabled are understood by few people (sometimes only one) and they become the only available “communication gates”. Even in such cases though, the dominance of a mediator may be limited by strengthening the feeling of control over communication situation, intentionality and making decisions that is always an attribute of self-reliance and independence.

From the point of view of the psychology of social contacts and interpersonal communication an ideal translation setup would be with a transparent, “see-through”, neutral mediator and complete correspondence of text A and text B. “The position of interpreters in the process of communication is unusual. They are in the middle. Being neither a sender nor a receiver, an interpreter is not only an interlocutor but, first of all, a part of the process itself. Because of that, they must be invisible” [8]. Obviously, such an ideal setup does not exist and not all agree on this point, for example Metzger “deconstructed myth of neutrality” [11]. But still most people expect that mediators should be a non-aligned and

detached medium. A simplified scheme of an optimal indirect communication with a person with disability should be like in a Fig. 2.

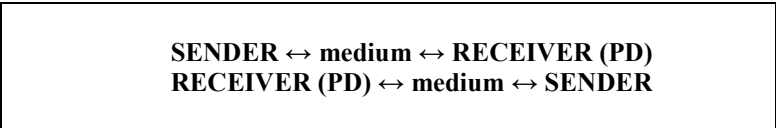


Fig. 2. Optimal indirect communication of person with disability with the roles of a sender and a receiver exposed (the size of the letters symbolizes primary and secondary role in the communication act: **medium** = language mediator; **(PD)** = a person with disability)
Source: own elaboration.

Nevertheless, as stated above, in practice we can experience various distortions coming from decreasing the role of one or both sides and excessive exposure of the role of interpreter/mediator. Possible relations are in a Fig. 3.

1)	sender ↔ MEDIUM ↔ receiver (PD) sender (PD) ↔ MEDIUM ↔ receiver
2)	sender ↔ MEDIUM ↔ RECEIVER (PD) SENDER ((PD) ↔ MEDIUM ↔ receiver
3)	SENDER ↔ MEDIUM ↔ receiver (PD) sender (PD) ↔ MEDIUM ↔ RECEIVER

Fig. 3. Indirect communication of person with disability disturbed by excessive exposure of the role of a mediator (the size of the letters symbolizes primary and secondary role in the communication act: **medium** = language mediator; **(PD)** = a person with disability)
Source: own elaboration.

The schemes in Table 3 illustrate the following cases of indirect communication disturbed by excessive exposure of the role of a mediator:

1. diminished roles of both sides of communication – a mediator takes the initiative, dominates during the act of communication, practically steers it; the sides of the translation become passive, communication intention of both sides becomes limited only to the necessary minimum or the willingness to communicate may even disappear.
2. the communication side with no disability is marginalized – a conversation practically takes place between a mediator and a person with disability; they make several agreements and additional explanations; the other side becomes passive and may feel uncertain not knowing the meaning of the agreements; the side may have doubts whether its communicate was conveyed properly.

3. the communication side with disability is marginalized both as a sender and as a receiver – the conversation takes place between an interpreter and a healthy side of a communication; person with disability becomes passive and uncertain similarly to the situation described in point 2; lost control over the situation; communication intentions become limited and a disabled person often awaits for a mediator to decide upon certain things with the other side only. A generalization linking the cause of marginalization with disability may breed in the conscience of the person with disability.

Especially cases 1 and 3 show the strengthening of the dependence of a person with disability. Nonetheless, I believe that the model of indirect communication with equally exposed roles of a sender, a mediator and a receiver should not be treated as distorted. It is illustrated by the next frame (Fig. 4).

SENDER ↔ MEDIUM ↔ RECEIVER (PD)
RECEIVER (PD) ↔ MEDIUM ↔ SENDER

Fig. 4. Indirect communication of person with disability with equal roles of all three subjects of communication situation (the size of the letters symbolizes primary and secondary role in the communication act: **medium** = language mediator; **(PD)** = a person with disability)

Source: own elaboration.

Such setup is acceptable and may be beneficial for both a sender and a receiver as their primary roles in the process of communication remain. In connection with the theory of communication within social interactions by P. Watzlawick [6], it may be stated that a supportive (service) role of an interpreter towards the need of communication is of complementary character against the need of communication from both sides. It may be debatable if one perceives an interpreter as a necessary condition for communication to occur between people so dependent from mediation; interpreter – as a professionalist and a specialist, a person who controls situation and supports helpless communication sides experiencing various negative emotions like anxiety, uncertainty, embarrassment or irritation. Good interpreters realize the fact although it is not an easy task. According to B. Fraser and H. Titchen Beeth “being a mediator, trying to be invisible or, at least, transparent and devoting so much time to analyze other people’s identities may lead to rapid exhaustion” [8]. It is, however, possible with self-limitations coming from the awareness of one’s willingness in the whole process. It is a suspension of an existing hierarchy increasing the chance for communication to become successful and complete. Fig. 5 presents such situation. All three persons taking part in indirect communication process accent their presence and they are all subjects of a communication situation. Although mediators lose their ‘transparency’ but it happens with the acceptance or even with a request from both sides of a translation. Although their professionalism obliges them to refrain from giving advices and sharing opinions, they are sometimes the only source of knowledge on the reasons behind an unsuccessful

communication. We can observe such situations at various universities while interpreting lectures to sign language for students with hearing disturbances. While mediating contacts among students they are often forced to explain the context of applied didactic solutions difficult to understand by the other side (e.g. what a deaf student needs a permission to record lectures; why they are unable to take notes from lectures; why they ask for a test composed of closed questions, etc.). Interpreters do not only interpret or translate thing e.g. in offices and public institutions but also help disabled to move around such institution, to fill various applications or petitions, to search for various sources of information. Practice shows that such current help from an interpreter is invaluable but some additional regulations should be taken into consideration:

- if an interpreter-mediator cannot become a spokesman of one side only because it may result in losing credibility,
- the sequences of an utterance of other person and conditions and context, must be clearly separated – the sides of an interpreting have the right to know when conveyed communicates are exact words of an interlocutor and when they are interpreter's words,
- it is unacceptable to modify and manipulate the content of an utterance of either side just to make it easier to accept by the other side [9].

There are some contradictions to the Ethic Code of and interpreter e.g. to the rule of impartiality “an interpreter is the only participant of interpreting that knows both environments and both languages so he has an advantage over the remaining sides of the interpreting. A high quality social communication is possible only with keeping impartiality and without using the advantage” [9]. When we observe the size of roles – the risk of dependence increases: the responsibility is not only to convey information to a receiver but also finding a solution to a problem. It also seems appropriate to define linguistic mediation as a form of discourse, and such analysis can contribute a lot to understand what takes place between people in the interpreting process [11, 19].

Risk of initiating communication only in presence or through mediator

The problem has already been mentioned before and pointed out, inter alia, by quoted von Tetzchner and Martinsen [20]. Communication takes place only in particular situations and in presence of a trusted language mediator. Obviously, we can talk about such dependence in the case of one mediator who is the only person able to understand a person with disability. The problem may get worse by choosing exclusive communication method that requires a special preparation from the participants – not only with disabilities – to be able to use it. When hearing damages are concerned, we can often observe a disadvantageous situation when a method of communication is mastered by only one person in a family – e.g. a mother or a father who teaches sign language or cued speech. That is why developmental and methodical premises of communication self-reliance are composed of several rules:

1. The choice of communication method that would isolate a person with disability in a minimal possible way from other users of a mother tongue, people from the closest surroundings, peers at school or Internet society etc. Sometimes a communication method useful at a certain level of development may – unfortunately – become a trap that closes a person in a communication ghetto. The choice of an alternative communication method should always have its deeper justification – psychological, pedagogical, physiological, ethical or anthropological. When acknowledging teleology and anthropology as factors determining actions of a special pedagogue it should refer to such aims-values like integration, self-reliance (autonomy), dignity of a person with disability.
2. Building communication environment around a user of alternative and supportive communication forms – spreading the chosen form within a society and environment of the user. Such actions should be taken in parallel to introducing a person with disability to a certain system of communicating [20]. The final scale of the environment will define the range of communicational independence of the person with disability.
3. Breaking the monopoly of one or few people communicating with a person with disability, especially a child entering social world and mastering communication methods. Even with methods with limited number of users it is possible to create occasions to initiate contacts with people – direct, or e.g. online, to initiate contacts with other people to use communication as an instrumental skill (with an amplifying effect through a successful communication process).

Risk of a “social filter”

The communication process between people is not only an exchange of words: it is also non-verbal communication, exchanging looks, mimics or proxemics carrying rich content about relations between people. It is also a code of ritual behaviors connected to entering various social roles. They are a sing of communication competences. This area contains a whole wealth of signs and their interpretation limited by the participation of a language mediator. There are two active mechanisms here:

- attention distortion: a person using a communication mediation distracts attention when trying to pay attention both to an interpreter and a proper communication partner; we may expect a situation when one or both persons concentrate exclusively on the mediator,
- “social filter” disturbing the attribution process – default attributing of motives and placing the feeling of control.

Attributions are a natural phenomenon in interpersonal contacts and – despite some false tendencies while judging situations by people – they allow to regulate own image of the world and social relations [7]. The “filter” is connected with mediation – it limits a natural income of information that might

be the basis for initiating attribution process. On the other hand, it should be underlined that in the described situation some processes of indirect attribution are initiated through the interpreter/mediator. In the relation initial sender – receiver, an eventual change of grammatical form of an utterance is also important for attribution (1st person communicate *I would like* may be passed as a 3rd person *he would like*) or a divergence between the subjects of utterances of a sender and a mediator (a mediator says in 1st person *I would like* but he does not speak about himself but only repeats sender's words verbatim). In such grammatical and situational context, in connection to the content of an utterance, attributions may create differently I respect to the subject of the communicate we receive [7]. The “filter” concerns also the role of an impression. In case of indirect communication some generalization takes place – identification of a partner of an interaction with a mediator. Some features of a mediator may be connected to the person he represents in a conversation. It is a quite strong mechanism and because of that skillful negotiators choose their companions of negotiations carefully, following the rule *my companion (my interpreter/my mediator) reflects me* [7].

The role of distortions in attribution process caused by the “social filter” should not be dismissed because of yet another reason. The contemporary approach to the theory of attribution defines its role clearly in building so called studied helplessness [7]. According the theory, the way we perceive interaction partner and his role in proceedings of various situations has a great value not only in shaping personal attitude towards him. It also influences the values attributed to successes and failures, the feeling of control and influence on various events. It shows itself during cognitive, emotional and motivational processes. It may also have serious results in functioning of people and their self-evaluation. Contemporary empirical research regarding attribution processes connect them with e.g. behaviors in difficult situations and individual proceedings of stress reactions, the risk of depression or health-related behavior of a person (including dealing with disability, with the problem of losing good health or other traumatic events) [7]. Studied helplessness is definitely a factor that limits independence and sometimes it shows itself very early.

Risk of “protective umbrella” and isolation

Another area of special human dependence is connected with having an interpreter or a communication mediator in places that people constantly meet each other. Sign language interpreters who accompany students during learning are a good example. An interesting phenomenon in integrative schools was spotted by M.T. Weiner i M. Miller. In such schools deaf students were often victims of bullying in specific places. They might expect aggression from their peers in areas out of a direct control, e.g. on a way back home. At school, they were visibly under the protective umbrella [22]. Especially when there is a supportive teacher working in a class, an assistant or an interpreter of sign

language – they isolate the student from peers and unconsciously becomes a personal protection of the child. Isolation does not allow to enter a group fully, to know each other well and when a lesson ends there is a signal of the end of protection and a feeling of impunity occurs.

Another example of the specific function of interpreters comes from an academy where a deaf student, coming from a deaf family and using sign language but at the same time functioning in Polish language, asked an interpreter for help. She read words from lips and she was speaking with legible articulation. The direct cause for searching for an interpreter was a growing tension between herself and other students who did not understand problems connected with deafness: they did not want to lend lecture notes, did not understand why the deaf friend does not make them herself during lectures, etc. Loneliness and the feeling of being misunderstood were so great that she seriously thought of quitting studies. “That was the most difficult period for me. I could not live peacefully and I was constantly embittered and I had some dark clouds above my head like quitting studies” [deaf student – own research]. Introducing a sign language interpreter changed the situation radically: “When the INTERPRETER came in it was a great happiness for me. I finally had someone to laugh and to cry with. I started to think positive. I liked to go to all lectures because thanks to the interpreter I started to understand better” [deaf student – own research]. The girl said several times that she does not feel lonely with the interpreter because they are together all the time and she can ignore mean behaviors of the friends from the group. The example not only proves that Weiner and Miller [22] were right but also shows a malfunction of the “protective umbrella” of an interpreter or other language mediator being constantly present next to a ward, not only little children.

Risk of lack of personal relations – instrumental dependency

Another aspect of a communication supported by w mediator is a difficult and tender problem of the relations of disabled towards their interpreters. It can be spotted during a longer cooperation with the same interpreter. Seldom – in case of incidental interpretations. One of the negative scenarios of developing personal relation may be an objective and instrumental treating of a language mediator by a person with disability. In fact, in such situation we cannot talk about a personal relation as sometimes we may even witness some signs of dehumanization towards an interpreter. Various observations and confessions of sign language interpreters show that sometimes deaf people treat them as their property, their slaves, they do not care about them and sometimes even try to show their power as clients. That does not – let’s hope so – happen often (I do not know any research treating about this problem) but especially difficult in practice. They cause mutual charges, insinuations, sometimes it even results in a refusal to interpret for certain people. It had to be said and it is necessary to think about the mechanism of such disturbances of interpersonal relations.

From a psychologist's point of view there are two the most probable explanations to such behaviors:

- it may be treated as a symptom of a demanding approach,
- it may be a mild form of dehumanization in interpersonal relations.

The problem of demands is often mentioned in the context of working for people with disabilities. Hale (1996) speaks about difficulties in normal social interactions caused by negative experiences connected with disability. These experiences, may result in socially unaccepted behaviors being the reason for stereotypical etiquettes characterizing people with disabilities e.g. parading and boasting about one's disability, demanding, auto-aggressive, having major complexes, overcurious and aggressive, demanding [1]. This is an often image of people with disabilities in the eyes of officials, and other people offering help services. Sometimes such behaviors are mentioned by interpreters and communication mediators.

Demanding attitude is excessive demands disproportionate to the actual needs of a person with disability, too high in comparison with actual help possibilities and accusing others for the situation. It occurs in various forms and refers to different areas of life. It is worth underlining here that in Polish research on the demanding attitude there were no signs of the attitude stronger in case of people with disabilities, although the factor of people presenting such attitudes is very high – it is almost a half of the society [19]. “Demanding attitude has different forms – Stanisławski writes – It may come from helplessness, oversensitivity, egoism, calculation or from the lack of a basic knowledge on where to get a particular support. “Mercy” is one pole of the demanding attitude. On the other there are demonstrative stands. They usually are a tone of a voice and sometimes even a verbal aggression” [19].

In academies, we may observe not only putting guilt for failed exam onto interpreters but also expectation that the interpreters will cheat during exams (the situation is unacceptable and it breaks the ethical code of an interpreter!) or prepare written forms for students etc. Additionally, there are situations when a student does not inform an interpreter about his planned absence, disdains their work (when the student, for whom the interpreting is prepared, reads a comic), the way they address interpreters. I would like to emphasize once again that these situations may be of an incidental character with the percentage of disturbed interpersonal relations similar to the one of healthy people.

Another explanation for shaping an instrumental relation of people with disabilities towards their language mediators is the dehumanization phenomenon – in its mild form. We can observe such form of dehumanization in various offices, in the work of officials or even medical personnel and pedagogues treating a client, a patient or a student not as a human being but rather as a “case”, “number” or “daily number”. It also works the other way round – clients, patients or students do not see a human being on the other side but rather an official. It should be remembered that dehumanization is a form of a defensive mechanism in which on the cognitive level a deconstruction of a social reality

image takes place. Changes within perception of others are to deliver the lack of a psychological comfort while performing certain activities or tasks that could cause moral conflict and that cannot be avoided (e.g. the necessity to take a certain benefit from a person, the necessity to cause pain, to fulfill certain formal recommendations with no option to take somebody's subjective situation into consideration). It is easier to cause pain, suffering, to humiliate somebody, to be cruel or hostile when we do not perceive him as a human being. It is easier to expect an interpreter to be "at one's beck and call", always available when he is not perceived as a human being but rather as a "interpreting robot". What is more, such attitude towards an interpreter may be a kind of a "punishment" for being dependent from his help. In the applied defense mechanism people dependent from other try to decrease the meaning and value of the people who prove the communication dependence, whose constant attendance helps as much as stigmatizes. Such decrease may be achieved through presenting the person as an object. Unfortunately, it cannot be accepted. You can discuss the "invisibility" of an interpreter, but its subjectivity should be obvious [11].

Also in a case when there is no option of refusal to cooperate with an unaccepted interpreter, the line of defense of a person with disability may be the objective treating.

Risk of excessive attachment – personal dependency

The last of the analyzed areas of risk concerns the possibility of excessive attachment of a person with disability to a language mediator [18]. On the one hand, it may result from the situation described above, when a mediator is the only way to contact outer world. His presence is a reward itself for a person with disability and it causes positive emotions or even such feeling as gratitude, sympathy, adoration. For people with small social experience – and people with disabilities often have such experience on a low level – it may be hard to define their own feelings. In noticeably limited social contacts the person of a language mediator, an interpreter, may be one of very few people constantly met who are not family members [17]. Naturally, it also applies to other specialists e.g. therapists working with a disabled person. They may have to cope with a substitutive function of a companion, a friend or even a person to love for the disabled. Intensity common being together may be sometimes confused with the level of intimacy. With a shortage of other contacts the meaning of these contacts may be overestimated and that is why while working with people with disabilities mutual relations should be carefully observed. It is crucial to:

- define exactly own professional role,
- setting rules and negotiating the boundaries of the contact,
- balancing between interpersonal closeness and openness and professional distance,
- doing every possible thing to avoid excessive attachment of the ward and additional commitments (it does not mean there is a complete ban

on initiating real friendship but it cannot be treated instrumentally and temporarily; a friendship is a root of commitments and if we enter a closer relation with somebody – we must meet that obligation).

Excessive attachment to the person of a communication mediator may be a problem for both the person attached and the mediator himself. On the one hand – it is all about respecting other people's feelings. On the other hand – avoiding troublesome professional situations, avoiding imposing contacts and provoking situations that impose them. In a radically difficult situation a change of the person of mediator should be considered.

Conclusion

The previous analysis of the problems of deaf people (and in general – persons with disabilities) who need help from a language mediator showed numerous dilemmas and areas of risk connected to such form of help that change their place to the continuum between independence and dependence. When setting up an interpreters' service, attention should be paid to the potential risks of the secondary effects of a long-term dependency relationship. To avoid them, much depends on the professionalism and competence of the interpreter – not only language and technical but also cognitive and social skills [10, 13]. In practice, the support of people with disabilities is still very limited in the sense of supervision of interpreters, communication facilitators, assistants as well as other professionals, and therefore a new task for the all psycho-pedagogic staff is emerging: reflective observation and monitoring of ongoing changes and relationships to prevent secondary disruption. There is an increasing awareness and more and more solutions for the independent life of persons with disabilities [2, 4]. But it is above all social relations marked, designate and will determine the old and new areas of independence and dependence.

References

- [1] **Bacelewska, D.:** Wsparcie emocjonalne w pracy socjalnej. Wyd. Śląsk, 2005.
- [2] **Blackmore, Th., Hodgkins, S.L.:** Discourse of Disabled Peoples' Organisation: Foucault, Bourdieu and Future Perspectives, [in:] Goodley D., Hughes B., Lannard D., Disability and Social Theory. New Developments and Directions, PANGRAVE MACMILLAN, Great Britain, 2012, p. 70-87.
- [3] **Charmaz, K.:** Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis, SAGE Publications, 2006.
- [4] CRPD-The Convention on the Rights of Persons with Disabilities, UN, 2006.
- [5] **Červinková, H., Gołębniak, B.D.** (eds.): Badania w działaniu: Pedagogika i antropologia, a zaangażowane. Wyd. Naukowe DSW, 2010.
- [6] **Dainton, M., Zelley, E.D.:** Applying Communication Theory for Professional Life: A Practical Introduction, 2nd Ed., SAGE Publications, 2011, 55-58.

- [7] **Försterling, F.:** Attributions. An Introduction to Theories, Research and Applications. Hove, Psychology Press Ltd., 2001.
- [8] **Fraser, B., Titchen Beeth, H.:** Ukryte życie tłumaczy. Poszukiwanie źródeł jakości, tłum. Piwowarczyk B. (br.) [online] Portal internetowy: Worldwide Translation, http://milingua.pl/pol/czytelnia,,ukryte_zycie_tlumaczy_poszukiwanie_zrodel_jakosci_bill_fraser_i_helen_,a,707.html [access: 28.10.2017].
- [9] Kodeks Etyczny Stowarzyszenia Tłumaczy Polskiego Języka Migowego [online], www.stpjm.org.pl/docs/kodeks.pdf [access: 18.10.2017].
- [10] **Leight, I.W., Andrews, J.F., Harris, R.L.:** Deaf Culture. Exploring Deaf Communities in the United States, Plural Publishing Inc., 2017.
- [11] **Loebl, W.:** O filozofii edukacji wspomagającej rozwój dzieci z głębokimi problemami w porozumiewaniu się (cz. II), Biuletyn Stowarzyszenia Mówić Bez Słów, Nr 3/10, 2005, 2-3.
- [12] **Metzger, M.:** Sign Language Interpreting. Deconstructing myth of neutrality. Gallaudet University Press, 1999.
- [13] **Monikowski, Ch., Winston, E.A.:** Interpreters and Interpreter Education, [in:], Marschark M., Spencer P.E. (eds.), The Oxford Books of Deaf Studies, Language, and Education, Vol. I, 2nd Ed., Oxford University Press, Inc., 2011, 367-379.
- [14] **Moore, D.F.:** The History of Language and Communication Issues in Deaf Education, [in:] Marschark M., Spencer P.E. (eds.), The Oxford Books of Deaf Studies, Language, and Education, Vol. II, 2nd Ed., Oxford University Press, Inc., 2011, 17-30.
- [15] **Nida, E.:** Zasady odpowiedniości, tłum. A. Skucińska, [in:] Bukowski P., Heydel M. (eds.), Współczesne teorie przekładu: Antologia, Wydawnictwo Znak, 2009, 53-69.
- [16] **Nida, E.:** Toward a Science of Translating: With Special Reference to Principles and Procedures Involved in Bible Translating, Michigan University, 1964, 145-155.
- [17] **Podgórska-Jachnik, D.:** Głusi. Emancypacje, Wyd. Naukowe WSP w Łodzi, 2013.
- [18] **Podgórska-Jachnik, D.:** Liberation or dependence? The problem of communication dependency caused by disability, Interdyscyplinarne Konteksty Pedagogiki Specjalnej, nr 12, 2016, 213-227.
- [19] **Roy C.:** Interpreting as a discours process. Oxford University Press, 2000.
- [20] **Stanisławski, P.:** Apetyt na przywileje, Integracja 2007 nr 2, <http://www.niepelnosprawni.pl/ledge/x/18819> - access: 8.10.2017.
- [21] **Tetzchner, S. von, Martinsen, H.:** Introduction to Augmentative and Alternative Communication, (2nd Ed.), Whurr, 2000, 87-89.
- [22] **Weiner, M.T., Miller, M.:** Deaf Children and Bullying: Directions For Future Research, American Annals of the Deaf, Vol. 151, No. 1, 2006, 64-68.

EVIDENCE BASED DEMENTIA PERSONAS: HUMAN FACTORS DESIGN FOR PEOPLE LIVING WITH DEMENTIA

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Abstract: The complex needs of people with dementia can create challenges when designing care environments. A Human Factors and Ergonomics (HFE) approach to the design of dementia care environments was used to address this challenge, and support wellbeing and independence for system users. Four individual personas (Alison, Barry, Christine and David) and a couple persona (Chris and Sally) were developed to represent the needs of people living with dementia. The aim was to facilitate the exchange of information and expertise between stakeholders and improve understanding of the characteristics of system users. An evidence-based approach involved extracting information from design, dementia, and clinical literature. This was followed by an iterative persona development process and a validation exercise to review the concept, content and applications. This paper outlines the development process, describes each persona and discusses current and potential applications.

Keywords: dementia, personas, care, environment.

Introduction

Dementia is a significant global issue, with an estimated 46 million people living with dementia worldwide [10]. This number is expected to rise to around 131.5 million people by 2050 [10]. The diverse nature of the symptoms of dementia, including cognitive, perceptual, functional and communicative considerations, results in challenges for providing appropriate care environments.

A Human Factors and Ergonomics (HFE) approach to dementia care design may therefore be useful as this would account for users' limitations whilst supporting users' capabilities, maximising wellbeing and independence and creating systems to fit their users [2].

To support such an approach to dementia design, it is vital that the stakeholders involved in the design process have a good understanding of the range of needs and symptoms associated with dementia in order that these can be

accounted for. Design tools such as personas are likely to be of use here as they showcase the characteristics of archetypal users of a particular product, meaning that subsequent designs can take these factors into account. Whilst personas are more commonly used in fields such as marketing and software design [1], they have potential use in the context of dementia design as they can be used to highlight the needs, symptoms, limitations and abilities of people with dementia. This may be particularly useful when designing environments for people with more advanced dementia who may be less able to take part in the design process due to more severe communication difficulties. It was proposed that dementia personas could assist stakeholders who have less knowledge of dementia to develop a better understanding of the condition, enabling them to be more mindful of relevant considerations when designing environments for people with dementia.

While the potential usefulness of personas in this context is clear, there are no known pre-existing personas which represent people with dementia; those which have represented older people have focussed more specifically on mobility related concerns (for example, the ArjoHuntleigh mobility gallery). For this reason, this research aimed to develop a set of evidence-based dementia design personas to be used as a discussion tool for stakeholders involved in the development of dementia care environments. The personas needed to be evidence-based rather than assumption-based as they are grounded in research rather than stereotypes or preconceptions that the creators have about a certain user group [1]. The iterative process for the development of these personas is outlined in this paper.

Initial persona development

A literature review was undertaken to explore current research based recommendations for dementia design. This used a systematic approach to searching databases for relevant literature, assessing the quality of the included literature, and examining and collating the findings of this literature. The review found several areas with near consensus on what was appropriate when designing for dementia; for example, access to outdoor areas [3], and wayfinding cues to correctly identify their bedroom [5, 8]. The findings on other aspects of dementia design such as lighting and behaviour were less clear, and there was less consensus, particularly for bright light therapy. One of the main findings of the review was that whilst many of the included papers had referred to one or more activities of daily living, there was limited consideration for activities of daily living that were relevant or important specifically for people with dementia. So, to ensure that the personas were relevant for people to dementia, and included the most important activities, a scoping study was undertaken to identify activities of daily living (ADL) for people with dementia.

ADL are generally considered to include activities such as eating, dressing, and bathing, but it was recognised that because people with dementia may have

different needs, abilities and limitations, their daily activities may also differ. The scoping study used an online questionnaire which was distributed to stakeholders working in healthcare and design fields related to dementia. These stakeholders included design professionals, for example architects with experience of designing spaces for people with dementia, and healthcare professionals such as occupational therapists and care staff working in dementia care homes. Participants were asked to consider activities which were particularly relevant to or important for people with dementia, as well as recommend design solutions to support these activities. It was found that eating, toileting, social interaction and physical activity were the most important activities, and a range of design solutions were suggested to support these activities that were broadly in line with the guidance in the dementia design literature. These activities were then used to develop the initial set of personas for 4 stages of dementia:

- A: Alison (early stage),
- B: Barry,
- C: Christine/Charles (renamed Christopher/Chris),
- D: David (late stage).

The initial personas (Fig. 1) were presented in a table format, with three sections; personal information, clinical information and design information. The personal information section included the persona name, age, and occupation. The clinical information section included details of the persona cognitive, perceptual, physical and communicative abilities, as well as their diagnosis. The design information section included information on difficulties that the persona had with ADL such as eating and toileting, and recommendations for the design of care environments to reduce the level of difficulty whilst engaging with these activities.

Further persona development

The initial personas (Version 1: V1) were evaluated with a focus group and interview study to assess whether the content and format were appropriate, and where they should be applied within the design process. As with the scoping study, participants represented a range of occupational backgrounds, including architects, care support workers, and care home developers. It was felt that the format of the V1 personas, was not particularly accessible or engaging and that important information might be missed. As well as this, V1 personas included design guidance for some of the issues such as wayfinding. This was not thought to be necessary as most design professionals working in dementia design would already be aware of these principles, and that where they were not, this information was already readily available in design guidelines. Furthermore, it was suggested that the personas only presented a snapshot each person, and did not adequately describe the fluctuations that could occur both during 24 hours and from day to day.



Alison	Female
Social information	Widowed
Age	70
Job (current/past)	Retired shop worker
Clinical condition	Early stage dementia (Alzheimer's Disease)
Current situation	Planning for long term care and possible future move to care home as disease progresses
Physical abilities	Independently mobile, small risk of falls
Cognitive abilities	Short term memory problems, struggles to learn new skills, sometimes forgets what she has just read
Perceptual abilities	May struggle to distinguish between different objects where there is little contrast
Communication	Sometimes has difficulties in finding the right word
Built environment issues	- Alison may find it difficult to locate the bathroom, so it is important that bathrooms are clearly visible. Signage on walls, doors and floors could help with this. Signs should use contrasting colours, relevant images and large, clear text¹. - Alison also faces difficulties inside the bathroom. Contrasting toilet seats can help to reduce her risk of falls², and fixtures such as dual lever taps which are both familiar and easy to use may enable her to engage with activities related to toileting such as handwashing³. - Signage could also assist Alison in finding the dining room. To help Alison to remember where she is and why she is there, the dining room should resemble a typical "homelike" dining room as far as possible⁴. To prevent falls and injuries, furniture such as tables and chairs should contrast well with the floor and walls².

¹ Signs with large clear text, high contrast colours and relevant images can help to promote bathroom finding when placed on walls or floors (1).

² Reduced contrast sensitivity has been shown to be one of the most important visual risk factors for falls (2). Coloured toilet seats which contrast with the toilet bowl can help to enhance visual abilities within the bathroom and may help to prevent falls. Similarly, using contrast between the walls, floors and furniture in dining areas may help to prevent falls occurring here.

³ Familiar fixtures may help to avoid confusion and enable people with dementia to complete tasks such as handwashing more independently (3).

⁴ Environments which would have looked familiar to a person with dementia during their early adulthood can help to counteract the difficulties which they experience as a result of dementia (4).

Fig. 1. Example of an initial persona

Source: own elaboration.

It was also felt that expanding the personal information section to include details of hobbies and interests would help to make the personas more realistic.

The personas were iteratively redrafted and reviewed (versions 2-5), with major changes to the format. Alongside an updated personal information section, each of the V5 personas contained information on symptoms, care needs and design needs.

These sections were further represented as good, average and bad days, to show how symptoms and needs may change. The V5 personas were presented as a wheel with a rotating cover to reveal colour coded sections (Fig. 2) as a traffic light system, with green for a good day, amber an average day and red a bad day.

A persona representing a couple was also developed to reflect the carers of people living with dementia, albeit not as the dementia persona. This largely followed the same format, but had an inner wheel to represent the needs of the person with dementia (Charles), and an outer wheel representing the needs of his wife and carer, Sally (Fig. 3).

Other changes were also made during the V2 to V5 iterations, including the addition of clinical assessment scores and icons. Clinical assessment scores were added for the Mini Mental State Exam (MMSE; [4]), the Montreal Cognitive Assessment (MoCA; [9]), the Addenbrooke's Clinical Examination III (ACE-III; [7]) and the Abbreviated Mental Test (AMT; [6]). The scores given to each persona were generated through examination of the guidance notes that accompanied each assessment tool, and discussion with an Occupational Therapist with extensive experience of working with people with dementia. Icons were added to illustrate the content within the persona wheels for ease of reference, and represented issues such as eyesight or hearing problems, and requiring assistance with ADL. A matrix was also created for each persona (Figures 4-8) which showed the symptoms, care needs and design needs across a good, average and bad days for each persona without having to scroll through the persona wheel. During this iteration, Charles was renamed Christopher (Chris) to reflect the fact that his symptoms and needs were of a similar level to Christine's symptoms and needs.

Validation of final personas

The final personas (Version 6, V6: Fig. 4 – Fig. 8) were then validated during a third study. A range of care homes that provided care for people with dementia were recruited to discuss and evaluate the personas with staff including care managers, nurses and care assistants. The homes represented a range of care with some solely accommodating people with dementia, whereas others housed people with dementia and people without dementia, sometimes in separate units. Some of the homes were purpose built, and some of the buildings were older. Participants were introduced to the concept of personas and given copies of the persona wheels. They were asked a series of questions about the personas such as the content and format, and potential usefulness in dementia care home design.

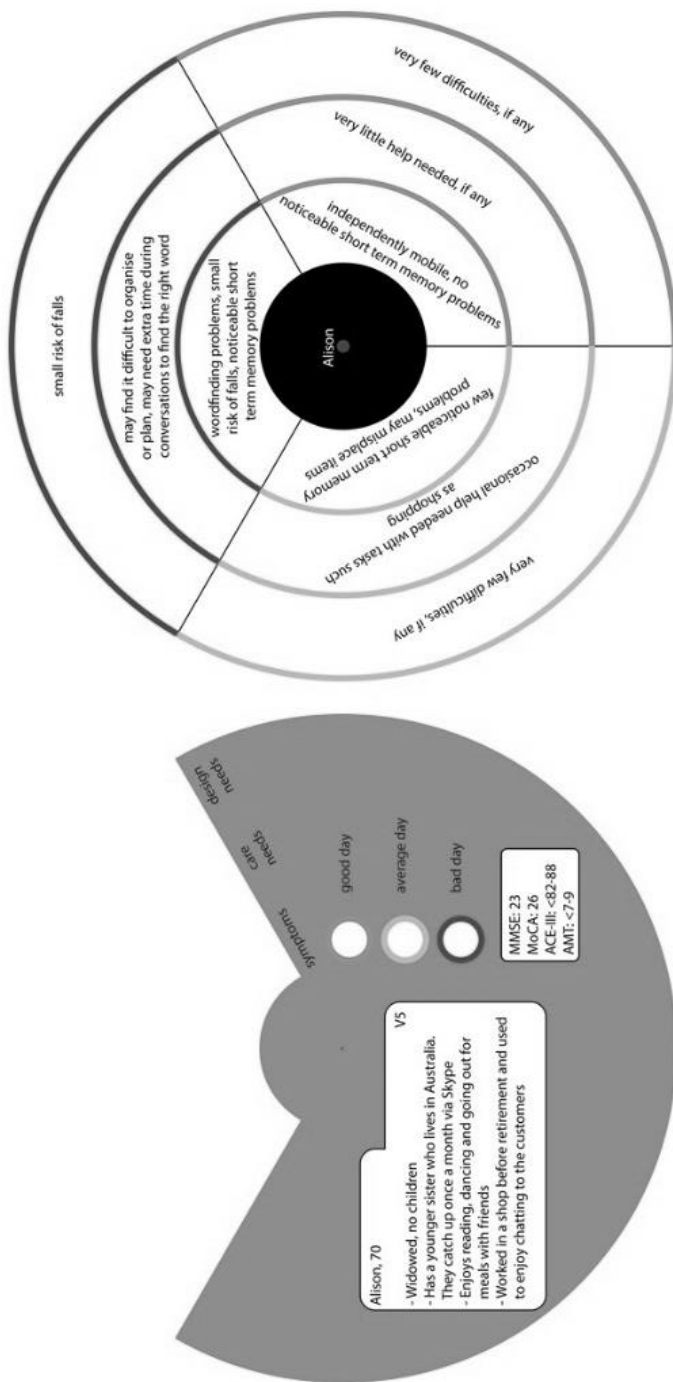


Fig. 2. Example of the components of a persona wheel (V5). The section on the left fits over the top of the wheel on the right and rotates to reveal the good, average or bad day
Source: own elaboration.

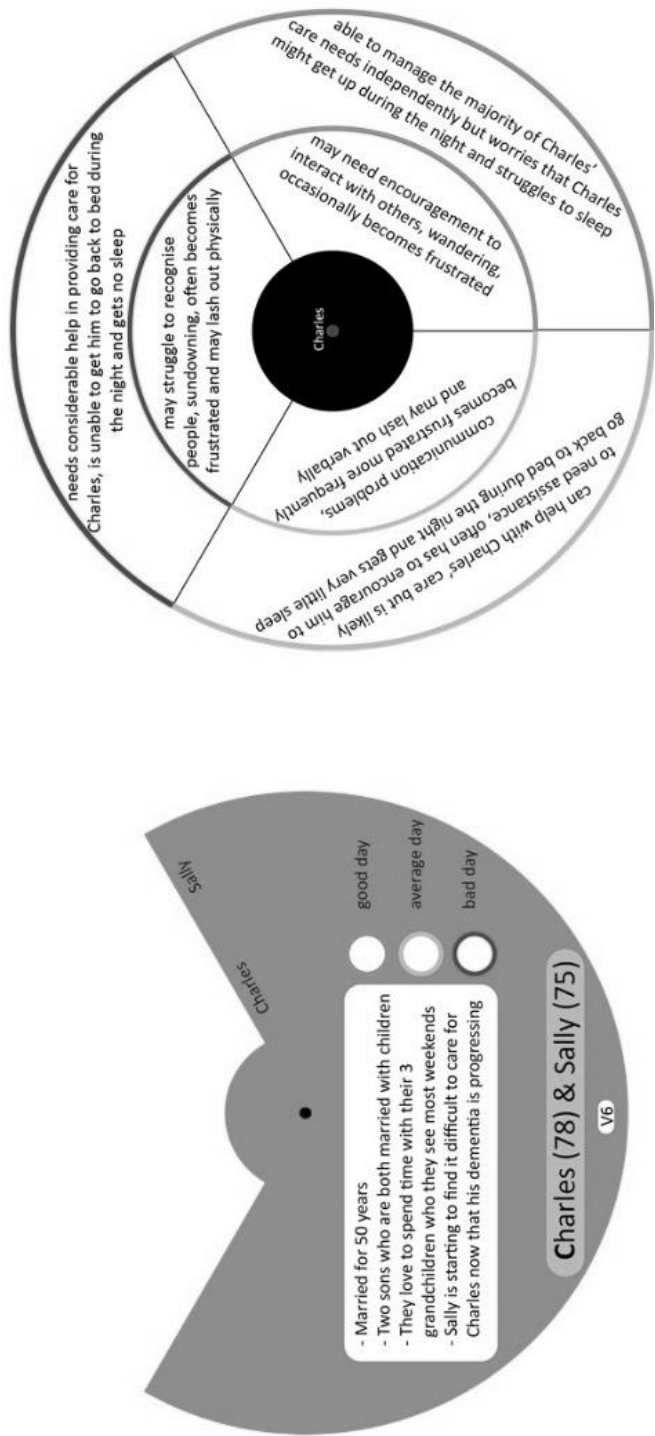


Fig. 3. Example of couple persona
Source: own elaboration.

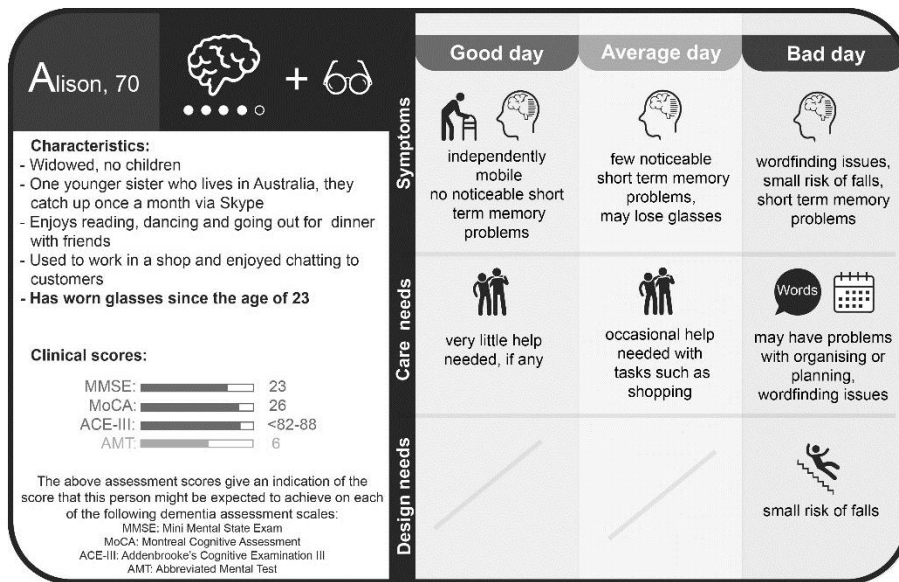


Fig. 4. Final Alison persona (matrix)

Source: own elaboration.

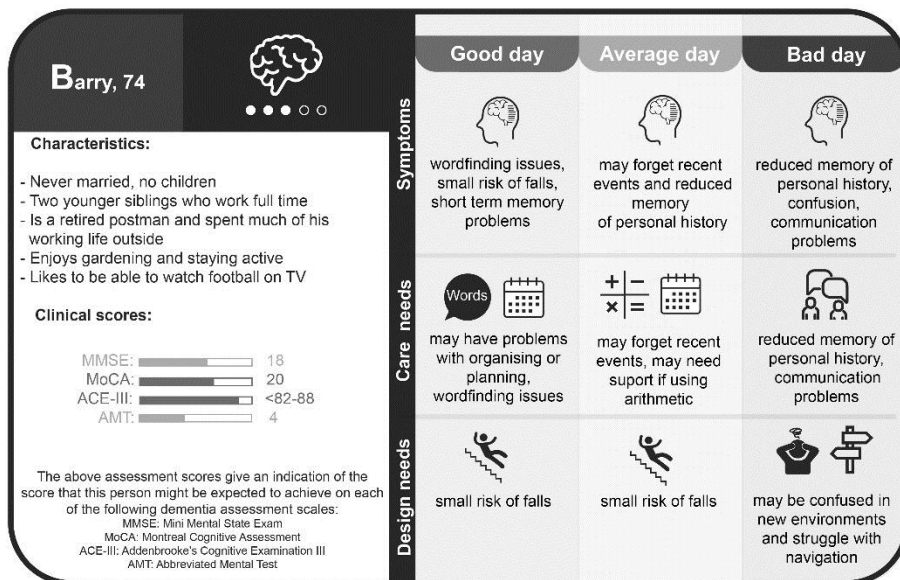


Fig. 5. Final Barry persona (matrix)

Source: own elaboration.

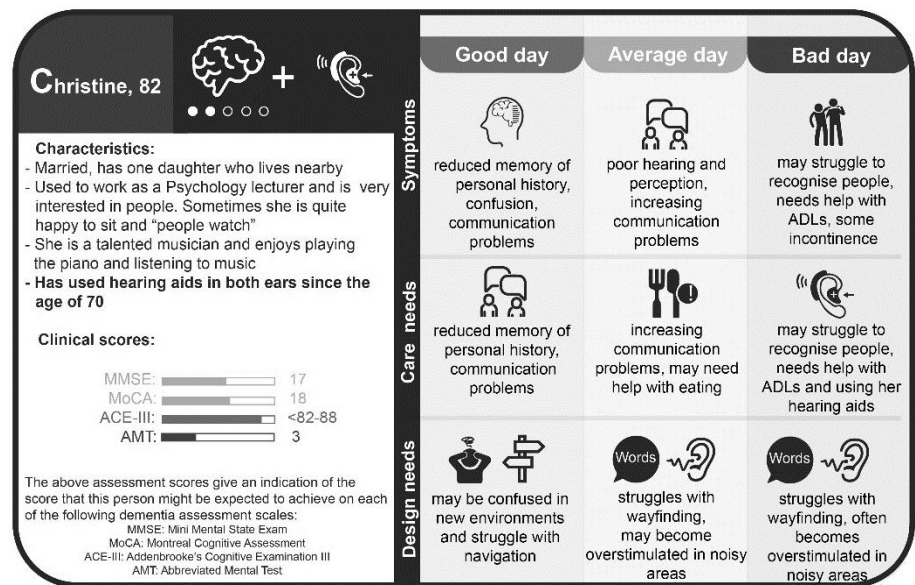


Fig. 6. Final Christine persona (matrix)
Source: own elaboration.

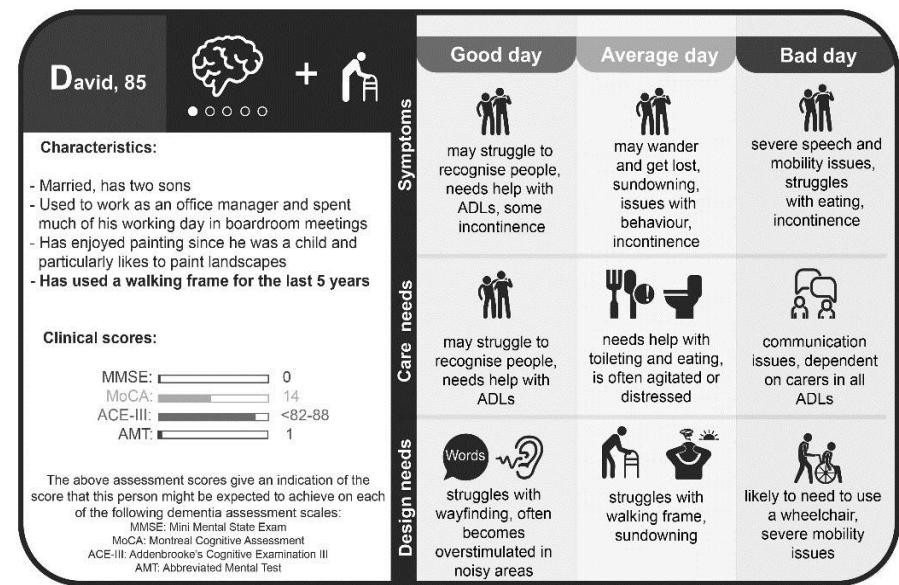


Fig. 7. Final David persona (matrix)
Source: own elaboration.

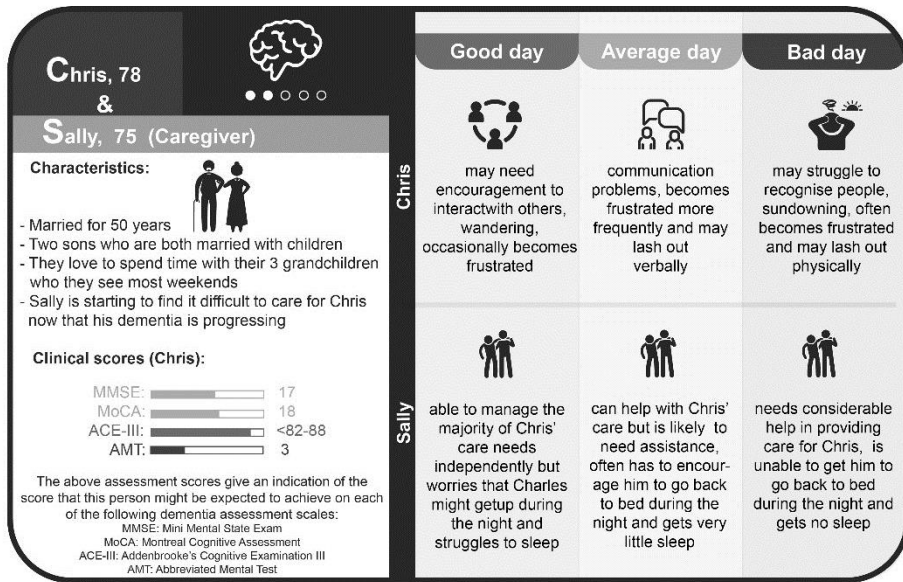


Fig. 8. Final Chris and Sally (Couple) persona (matrix)
Source: own elaboration.

Participants were also asked about features of the personas such as the colour coded good-average-bad days, and finally recommendations for further developments and applications. At each home, the researchers and participants discussed building design and environmental layout during a walkabout to explore the application of the personas for features that might be helpful or problematic for people with dementia.

The response to the personas was very positive, with participants suggesting that they were valuable representations of people with dementia and could potentially be adapted to represent actual care home residents for use in care delivery as a communication tool for shift handover. Several participants commented that they “recognised” the personas as needs and symptoms of actual residents. This became more apparent during the walkabout when participants identified features of the home that might cause difficulties for the personas with reference to actual residents. The inclusion of the icons in the final version was reported to be useful for quick reference, and particularly for staff whose first language was not English. The participants felt that the personas were a useful tool, and could see applications in both care home design and care delivery for people with dementia.

Discussion

This paper has described the use of HFE principles to develop a set of dementia design personas. The fact that these personas are evidence-based is

a particular strength as it addresses previous critiques of personas which may have been based on preconceptions and stereotypes which can be inaccurate and/or misleading. The results found that basing the personas development on research evidence has improved relevance by focussing on relevant activities (ADL). The initial scoping study specifically identified activities which are important in dementia care. Due to the fact that some of the most important activities identified in the scoping study were social interaction and physical activity, it is unlikely that basing the personas on current classifications of ADL would be adequate as these social interaction and physical activity are considered to be instrumental activities of daily living (iADL; important but non-essential activities) rather than ADL.

The involvement of stakeholders in the development and review of the personas is another strength of this research. This was a particularly important component of persona development to ensure that the content remained relevant and meaningful, and that the format was accessible.

One potential limitation of this research is that people living with dementia were not directly involved in the development of the personas. There were two reasons for this. Firstly, it was noted that while it would be possible to discuss the personas with those with early stage dementia, it may not be for those with more advanced dementia, as this group often struggle with communication. This could have resulted in only two out of four levels for the personas being discussed, which may have caused problems with validity. Secondly, each persona does not represent one specific individual with dementia, they are more generic and represent a range of people at each of the 4 stages. The third study adds validity as participants were able to “recognise” elements of actual residents in each persona suggesting that the personas do successfully represent this diversity.

Conclusion

This paper outlined the process to develop and validate an evidence based set of dementia personas to aid the design of dementia care environments. Grounding these personas in research evidence, and seeking feedback at various stages, has resulted in a robust and valid set of personas. It is recommended that future research should consider the additional applications for these personas in care delivery, for example at shift handovers.

References

- [1] **Adlin, T., Pruitt J.:** The Essential Persona Lifecycle – Your Guide to Building and Using Personas 2010.
- [2] **Dul, J., Bruder, R., Buckle, P., Carayon, P., Falzon, P., Marras, W.S., Wilson, J.R., van der Doelen, B.:** A strategy for human factors/ergonomics: developing the discipline and profession. *Ergonomics*. 55(4), 2012, 377-395.

- [3] **Edwards, C.A., McDonnell C., Merl H.:** An evaluation of a therapeutic garden's influence on the quality of life of aged care residents with dementia. *Dementia*. 12(4), 2013, 494-510.
- [4] **Folstein, M.F., Folstein, S.E., McHugh, P.R.:** Mini-mental state. *Journal of Psychiatric Research*, 12(3), 1975, 189-198.
- [5] **Gross, J., Harmon, M.E., Myers, R.A., Evans, R.L., Kay, N.R., Rodriguez-Charbonier, S., Herzog, T.R.:** Recognition of Self Among Persons With Dementia: Pictures Versus Names as Environments Supports. *Environment and Behaviour*, 36(3), 2004, 424-454.
- [6] **Hodkinson, H.M.:** Evaluation of a mental test score for assessment of mental impairment in the elderly. *Age & Ageing*, 1(4), 1972, 233-238.
- [7] **Hsieh, S., Schubert, S., Hoon, C., Mioshi, E. Hodges, J.R.:** Validation of the Addenbrooke's Cognitive Examination III in Frontotemporal Dementia and Alzheimer's Disease. *Dementia and Geriatric Cognitive Disorders*, 36, 2013, 242-250.
- [8] **Kovach, C., Weisman, G., Chaudhury, H., Calkins, M.:** Impacts of a therapeutic environment for dementia care. *American Journal of Alzheimer's Disease and Other Dementias*, 12(3), 1997, 99-110.
- [9] **Nasreddine, Z., Phillips, N., Bédirian V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J.L., Chertkow, H.:** The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, 53(4), 2005, 695-699.
- [10] **Prince, M., Wimo, A., Guerchet, M., Ali, G-C., Wu, Y-T., Prina, M., Yee Chan, K., Xia, Z.:** World Alzheimer Report 2015. The Global Impact of Dementia: An Analysis of Prevalence, Incidence, Cost and Trends 2015.

THE IMPORTANCE OF WORK FOR PEOPLE WITH DISABILITIES AND EVALUATION IMPOSED OBLIGATIONS OF EMPLOYERS

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Abstract: The paper is aimed at the analysis of the importance of work for people with the invalidity and the assessment of obligations in view to people with disfunctions. Presented elaboration authors presented terms of disability and its classification. In addition, they analyzed the Polish model of work and rehabilitation through professional activation for people with disability. Research of the subject constitute the most important part of the paper. Authors have build a research query and they run an examination on the importance of work for people with invalidity and the assessment of employers' obligation in view to disabled people.

Keywords: a person with invalidity, professional activation, employer, importance of work.

Introduction

A disabled person, just like any other Polish citizen has a guaranteed right to work. It is important to notice that work has not only its financial function. It can also fulfill many other needs. In case of disabled people the work is more and more frequently perceived as an important element of social rehabilitation and professional activation.

Taking under consideration statistics, the rate of professional activity of disabled people is rising every year. From 2007 to 2017 this rate grew from 21.1% to 29.6%. In addition, the rate of employment for the presented period grew for 10%, and the unemployment rate diminished for 8%. At present it reaches 8.1%. It is also important to notice that presented data refer to disabled people in economically productive age [10].

The term of disability

The definition of disability is very fluent and it is difficult to establish the meaning of the term precisely. Every human has periods of life, in which he or she has better or worse physical capacities or limitations. Things, which are easy for us today can become very difficult for us in a few years; they may be even impossible for us. Even if do not consider dysfunctions resulting from accidents,

we still must remember about numerous causes of disabilities and dysfunctions growing along with the age.

The official definition formed by the World Health Organization is:

A disable person is someone who's significant defects of the organism and its reduced capacity of functioning cause difficulties or disabilities in effective functioning in the society, in view to such factors, like sex, gender, age or external factors [3].

On the other hand, the Regulation from the 27th August 1997 on the occupational and social rehabilitation and on employing disabled people uses a different definition, which is useful mainly from the point of view of granting an invalidity status.

“Disabled people are those, who's physical, psychical or mental condition hampers or makes difficult or impossible social activities, especially those related to professional occupation for e certain period or permanently. This refers to people who have obtained a decision to qualify for one of three degrees of disability or a decision to obtain a partial or absolute disability to work. If such people are less than 16 years, then they can obtain a decision on the type and range of disability“ (Journal of Laws No. 1213, item 776 with changes) [9].

The term of disability has evolved in the terminology. According to the Polish PWN dictionary, disability is "a limitation or a lack of ability to perform activities in a way or range that is perceived as normal for a human and which results from a damage or dysfunction of the organism" [13].

In order to be formally declared a disable person one must fulfill requirements enclosed in the law on occupational and social rehabilitation and on the employment of disabled people.

Classification of disability

In this paper authors presented a classification of disabilities according to ICF (International Classification Functioning Disability and Health). The main goal of ICF is to establish a common language used for the description of health and of states related to health, including disabilities.

ICF bases on the modern definition of disability, which has overcome defects of definitions that referred to two extreme models: a medical and a social one.

The medical model presents disability as a personal problem, directly caused by a disease, injure or other disease condition that requires a medical help in form of individual treatment provided by qualified specialists. The medical model assumes that the purpose of the proceeding is to heal the individual or to adjust the person and change his or she's behavior.

On the other hand, the social model of disability perceives it mainly as a problem created by the society and the issue concerning the full social integration of individuals.

According to ICF, disability has a bio-social character; it is a multidimensional phenomena resulting from mutual interactions between people (including people

with dysfunctions) and the physical and social environment. Modern approach to the idea of disability suggested by ICF allows using this classification by a wide range of various users and for different purposes. ICF is a statistic, scientific, clinical and educational tool. It is worth to notice how useful it is as an instrument of the social policy and which should be used for the planning of the social policy within the range of disability and for preparing programs of intervention and their evaluations [4]. The Figure 1 shows the characteristics of the presentation of diseases by ICF.

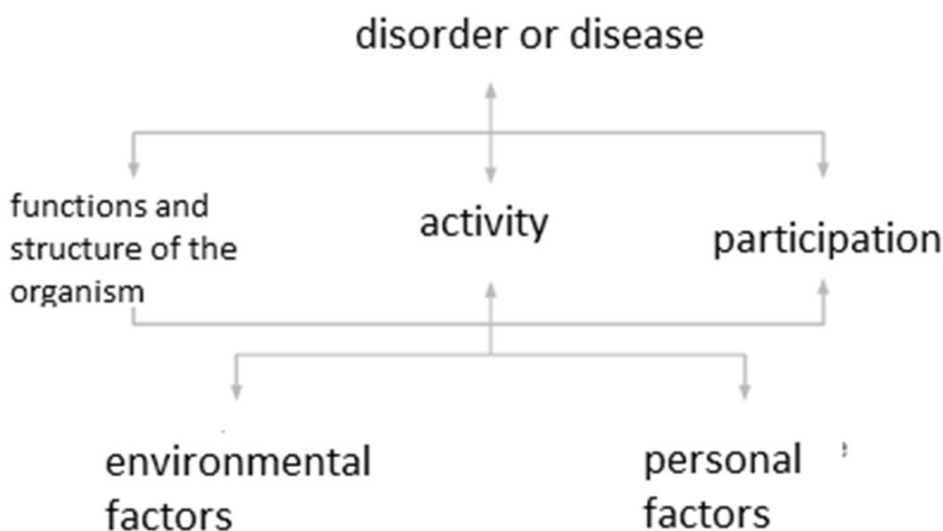


Fig. 1. Presentation of the age of examined people
Source: [4].

The first component, which is the state of disease, encloses functions and structures of the body; it divides into two classifications. One of them encloses the functioning (activities) of systems of the organism, the second one refers to the structure (construction) of the body. The second component states from activities and participation; it encloses the entire range of disciplines concerning the functioning both from the point of view of an individual and the entire society. Environmental factor affects every element of the functioning and disability; they are sorted by a certain key. The list opens with factors from the nearest environment of the individual, last factors concern the general environment. The list encloses also personal factors, which were not written down in view to their individual character for each person.

Work for people with disabilities

Work can be a very important element of man's life. The occupational activity allows fulfilling principal needs and it assures the sense of security.

Work can constitute a source of finance, it balances the time during the day, it is the foundation for new social relations, it can be a source of satisfaction and self-actualization [11]. Engaging people with disability into the occupational activation represents a very important element of the rehabilitation. Work allows disabled people to realize three significant determinants of their lives: financial, rehabilitation and social. Work has a crucial role for building their own image of themselves, the acceptance; it can give a meaning to their lives. In addition, employment prevents social exclusion [1].

Disabled people can be employed in occupational activity centers, in supported employment enterprises and on the opened labor market. Supported employment enterprises are institutions incurred in accordance with the law on occupational and social rehabilitation and on the employment of disabled people. Occupational activity centers are institutions that employ people with significant disability [5, 6].

Supported employment enterprises are a particular form of economic activity. their main purpose of functioning is to provide employment for people with disabilities and having limited abilities to perform occupational activities.

Supported employment enterprise is a company. However, it does not function to generate profits. It is focused on employing a large number of disabled people, it must be adjusted to their needs and constitute a basis for their rehabilitation, occupational activation and medical care [7, 8].

Work is included in the group of determinants that create possibilities to go back to partial, or even entire ability. The occupational activation create conditions for improving the general physical fitness and it is beneficent for the own-perception. The rehabilitation can be more effective in case of a person, who is occupationally active. One could also draw from the fact that the occupational activation can compensate limitations resulting from disability and improve the quality of life.

People with disabilities can find in work a chance to prevent their social exclusion and a way to fight against stereotypes. Moreover, it can give them a chance to live a balanced life [2]. More on these topics also wrote: A. Tokarska-Siudeja, D. Becker-Pestka, E. Ryżek, R. Śleboda, E. Kryńska, J. Sosnowska, M. Garbat, A. Paszkiewicz, D. Strauser, S. Piocha, E. Nadolna.

Own research

While analyzing the topic of the importance of work for people with a declared disability and assessing obligations of employers authors realized short pilot research. The research method was a direct interview. The study was made in the group of ten participants. Moreover, the research was anonymous and with use of a tool in the form of a questionnaire.

The survey was divided into three areas of information to be gained. The query included an imprint, in which participants were asked about their education, age, declared level of disability and its type.

Authors want to assess the importance of work for people with a declared disability. Therefore they asked about ways of finding work, the attitude toward work, the motivation to take up work and the influence of work on the examined person.

Authors also wanted to assess obligations of employers in view to verify the activity of the company for the rehabilitation of disabled people, scale of adaptation of workstations, medical care and the knowledge of law on disabled people. Respondents were people from small production and service enterprises. At this point, a broader description of enterprises is not taken into account due to the lack of consent of respondents. Research result are presented on following graphs.

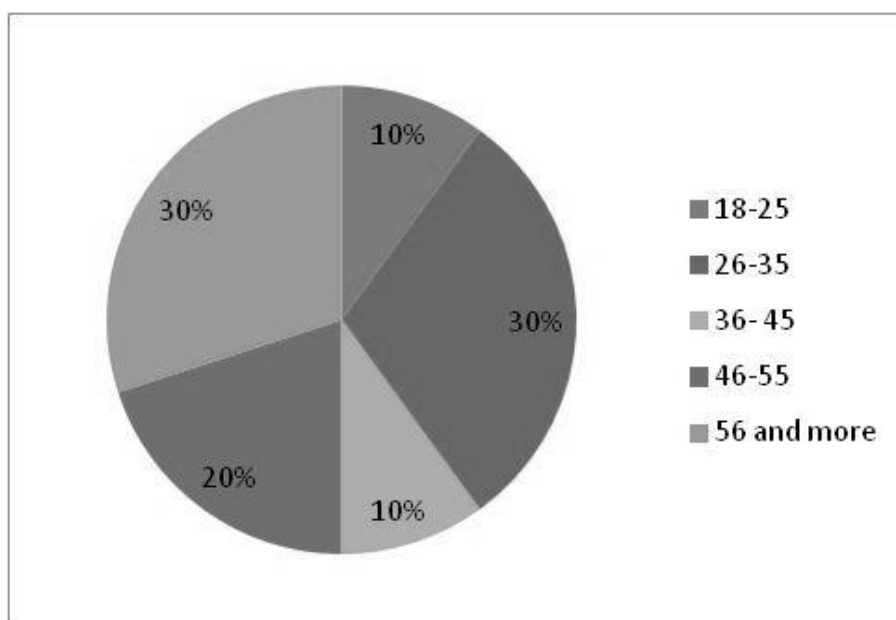


Fig. 2. Presentation of the age of examined people
Source: personal elaboration.

The graph shows that despite the small number of participants of the survey, it has been cared to ensure in different age. The majority of participants were in the group of aged from 26 to 35 and in the group of 56 and more.

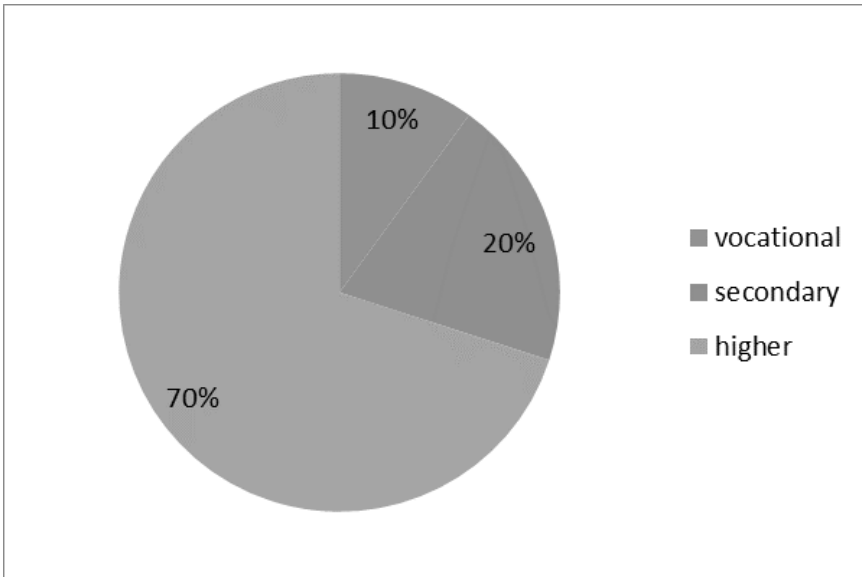


Fig. 3. Presentation of the level of education of examined people
Source: personal elaboration.

The majority of responding people were those, who had higher education.

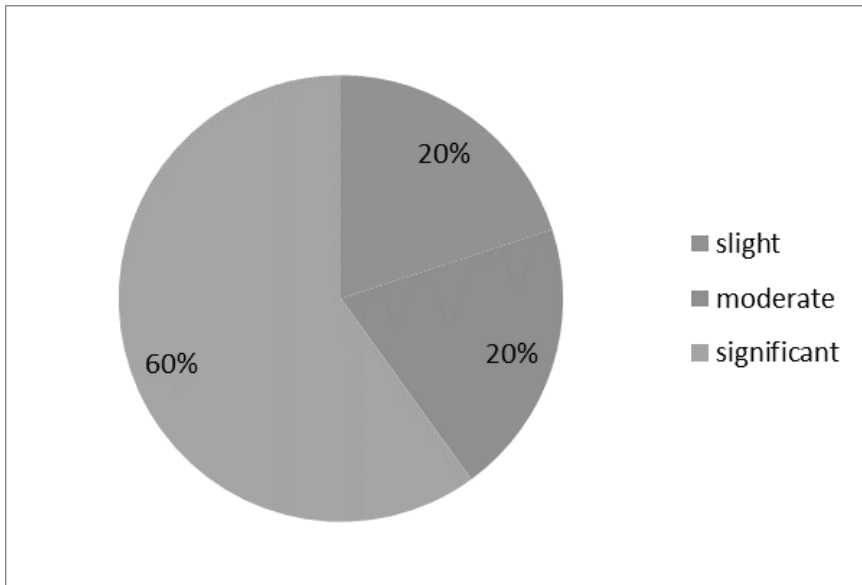


Fig. 4. Presentation of the level of disability of examined people
Source: personal elaboration.

The participants of the survey had in majority a declared significant range of disability. The survey took also under consideration responses given by people with a slight or moderate disability.

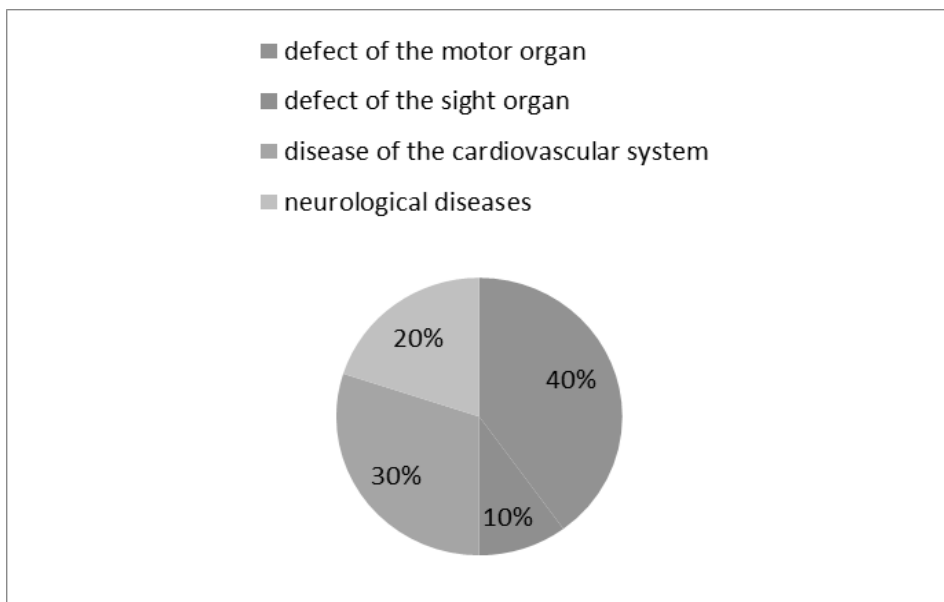


Fig. 5. Presentation of the type of disability of examined people
Source: personal elaboration.

The group of examined people enclose those with a declared disability of the cardiovascular system, of neurological diseases, defects of the eyesight or motor system of the organism.

Responses on question how the person has found the work were not presented on graphs in view to the identical character of these answers. All participants of the survey declared to find their work on basis of their own efforts. One participant declared to find work through an advertisement send to a student organization.

The question whether respondents like their occupation also gave identical answers – all participants declared to like their work and to perform their occupational activity with enthusiasm.

The most of respondents evaluated activities of their companies in view to performances for rehabilitation of disabled people as good. Unfortunately, the questionnaire form did not ask respondents to describe such actions. In addition, respondents were asked about the adaptation of job positions and medical care from the employer.

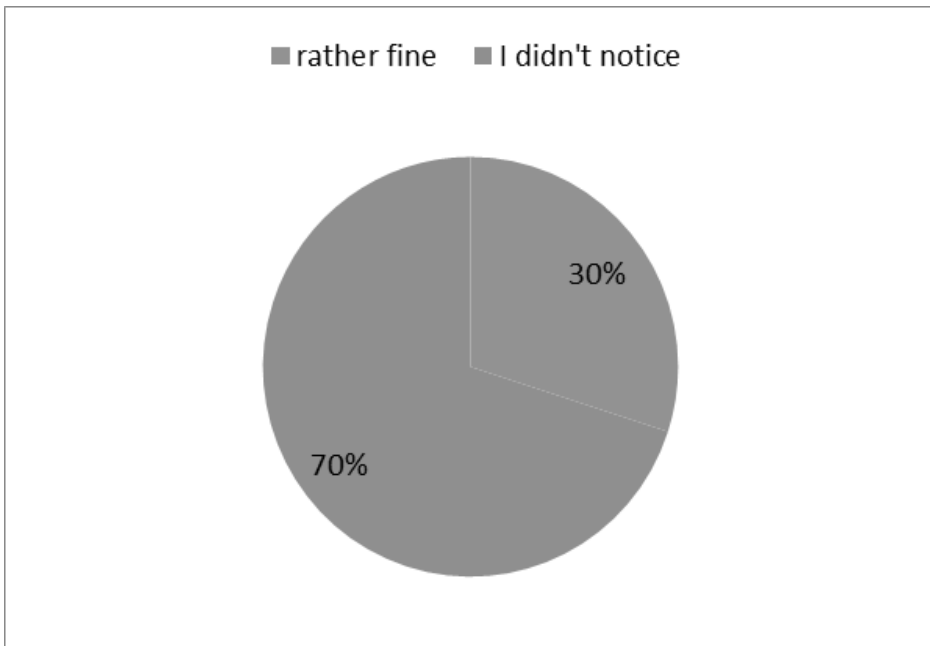


Fig. 6. Presentation of rehabilitation activities of the company
Source: personal elaboration.

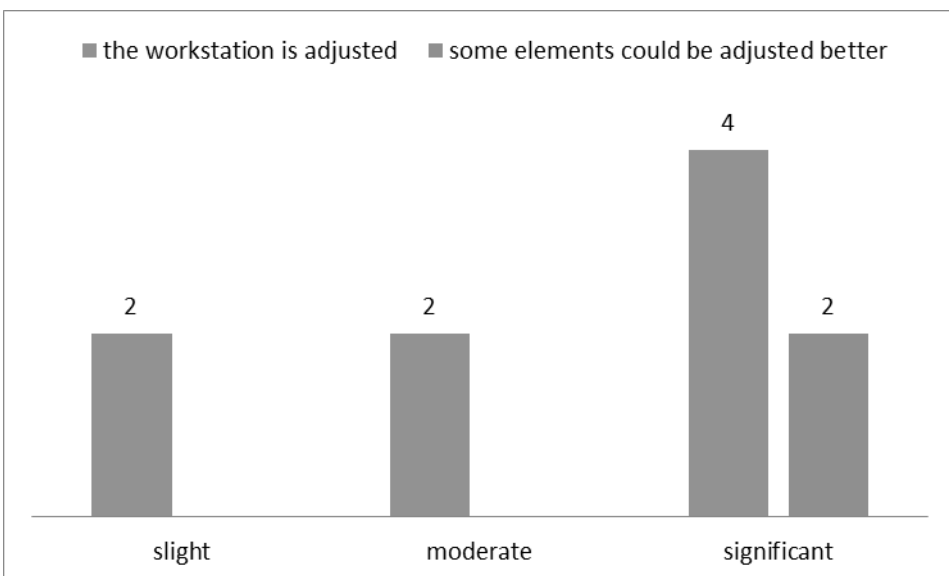


Fig. 7. Presentation of the adjustment of workstations for examined people
Source: personal elaboration.

In addition, it is worth to notice that two people with a significant disability mentioned in the graph claimed that some elements of their workstation could be better adjusted, were from the age interval from 35 to 45 and from 56 and more. In addition, there were people with a disability concerning their eyesight and motor systems.

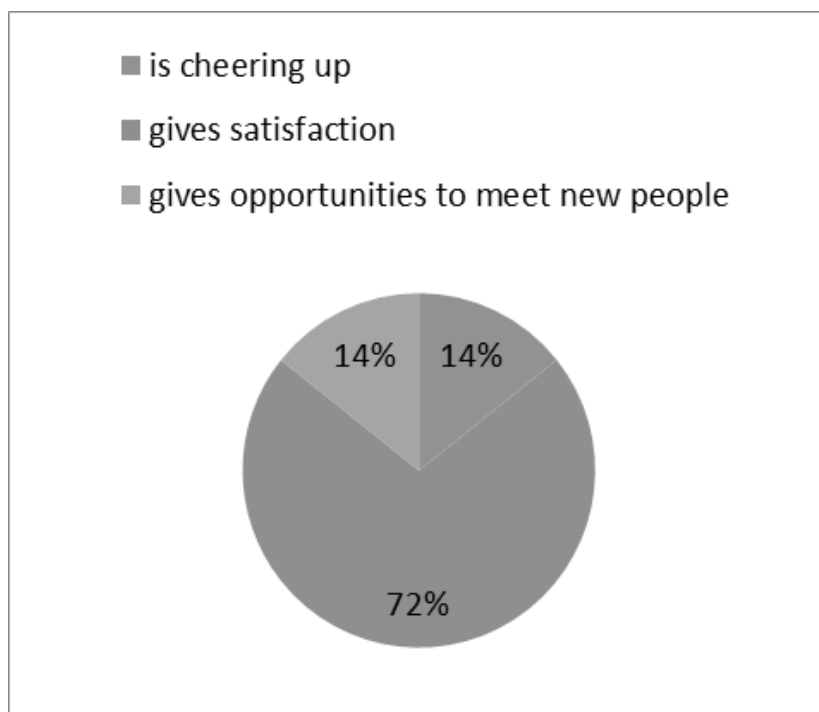


Fig. 8. Presentation of the influence of work on examined people
Source: personal elaboration.

All examined people find their work a source of satisfaction. In addition, two respondents pointed that work cheers them up and it is their source of new relationships.

All respondents answered the same to the question about the medical care provided by the employer – they didn't know a thing about it. Only one participant of the survey stated that the medical care is not suitable. It is worth to notice that this person knew the law on disabled people very well.

Respondents took their jobs mainly for financial reasons. Still, there were some statements that this reason was not their only motivation; they also declared that they needed new relationships and gaining experience.

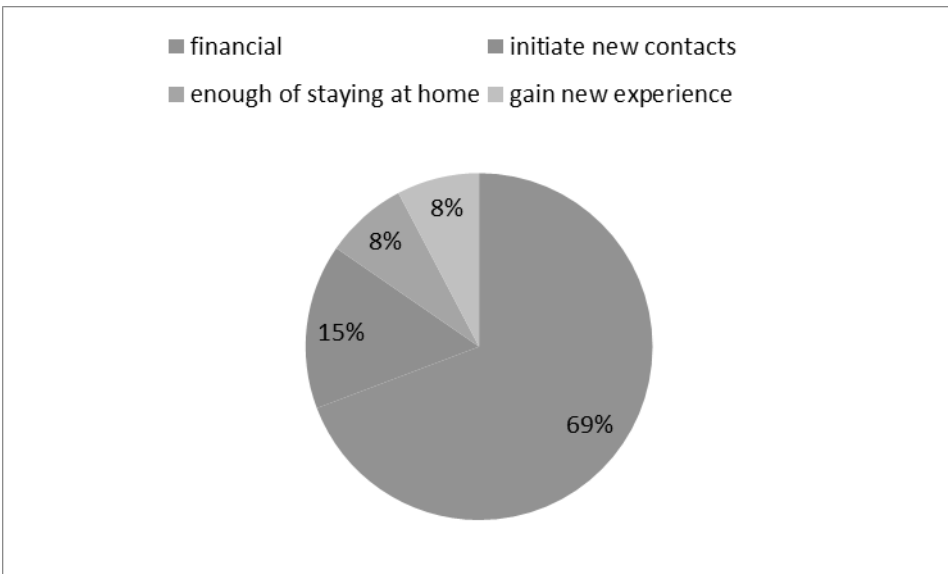


Fig. 9. Presentation of reasons for initiating occupational activity by examined people
Source: personal elaboration.

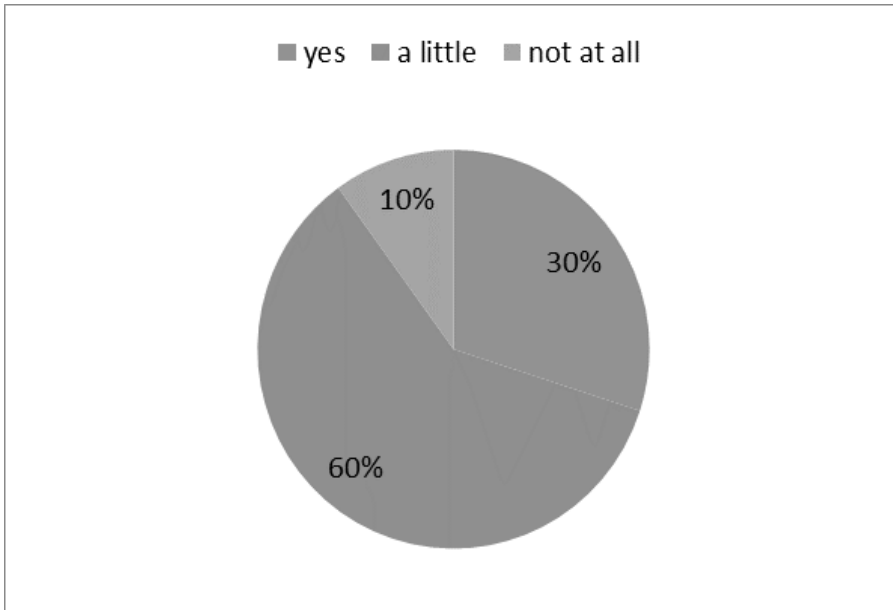


Fig. 10. Presentation of the knowledge of law on matters referring to examined people
Source: personal elaboration.

Unfortunately, the awareness and knowledge of the law on disabled people was pretty poor in the group of respondents. Only three participants declared to know regulations. The significant majority claimed to know the law only a little. Unfortunately, in view of the tool used in the research, which is subjective, authors could not define the term “a little”.

Summary and conclusions

The importance of work in the group of disabled people is growing every year. It depends on the level of disability or its type. The article presents a research made in a group of people with a significant level of disability and having a higher education. In their cases the disability was not a barrier for finding a job. People with a declared disability initiate work not only because of finance. They consider work as a chance for new relationships, gaining experience and a possibility to go out of their houses. The occupational activity has a positive impact on disabled people that took part of the survey. It was a source of satisfaction and good mood. Authors have assessed obligations of the employers towards disabled people and they took under consideration three important areas of the occupational activation. These areas are: adjusting workstations to delegated tasks, medical care and activities for rehabilitation of disabled people. In case of the medical care and rehabilitation, disabled people did not notice or did not have knowledge on activities of their employer in these areas. Unfortunately, the knowledge of the law on disabled people was poor in the groups of respondents. It is worth to notice that the knowledge of the law can be the basis for executing obligations from employers.

The proposal of improvements in the organization of work of people with disabilities are training courses organized for employees and employers. The awareness of both employees and employers about the rights they are entitled to in relation to people with disabilities and disabilities should be increased. In order to improve the organization of work of people with disabilities, this problem should be addressed individually and treated according to a case study.

References

- [1] **Becker-Pestka, D.:** Aktywizacja społeczna i zawodowa osób niepełnosprawnych – problemy i wyzwania. Colloquium Wydziału Nauk Humanistycznych i społecznych, Nr 4, 2012.
- [2] **Buchwald, T.:** Osoby niepełnosprawne i ich aktywizacja zawodowa na otwartym rynku pracy a polityka społeczna w Polsce. Programy wsparcia realizowane przez Fundację Aktywizacja, [in:] Niepełnosprawność – zagadnienia, problemy, rozwiązania, Nr 2, 2015, 15.
- [3] **Niewola, W.:** Vademecum dla osób niepełnosprawnych – przewodnik zawodowy. Część I. Podstawowe pojęcia, Centra Informacji i Planowania Kariery Zawodowej Wojewódzkiego Urzędu Pracy w Krakowie, 2009.

- [4] **Pietruszyńska-Wilmowska, A., Bilski, D.:** Międzynarodowa Klasyfikacja Funkcjonowania Niepełnosprawności i Zdrowia, [in:] Niepełnosprawność – zagadnienia, problemy, rozwiązania, Nr 2, 2013, 7.
- [5] **Piocha, S., Nadolna, E.:** Zatrudnienie osób niepełnosprawnych jako forma rehabilitacji zawodowej, Zeszyty Naukowe Ekonomiki i zarządzania Politechniki Koszalińskiej, nr 1, tom 3, 2009.
- [6] **Potok, A.:** Dylematy i wyzwania aktywizacji zawodowej osób niepełnosprawnych w Polsce, [in:] Studia Oeconomica Posnaniensia, Nr 2, 2014, 6.
- [7] **Styk, K.:** Aktywizacja zawodowa osób niepełnosprawnych w Polsce w świetle realizacji postanowień Konwencji o prawach osób niepełnosprawnych, Ekspertyza opracowana na potrzeby projektu „W stronę skutecznego modelu partycypacji obywatelskiej”, realizowanego w ramach programu Obywatele dla Demokracji, finansowanego z Funduszy EOG, 2014.
- [8] **Śleboda, R.:** Kierunek i poziom wykształcenia oraz aktywność zawodowa osób z niepełnosprawnością, [in:] Niepełnosprawność – zagadnienia, problemy, rozwiązania, Nr 2, 2012, 3.
- [9] Act of 27 August 1997 on Vocational and Social Rehabilitation and Employment of Persons with Disabilities, Journal of Laws, 1997-10-09, No. 123, item 776 with changes.
- [10] Quarterly and annual BAEL data – Statistics Poland 2017.
- [11] <http://www.ocwip.pl/informacje/wszystkie/zobacz/Znaczenie-pracy-w-zyciu-osoby-niepełnosprawnej> - accessed on 03.10.2017.
- [12] <http://www.pfron.pl> – accessed on 03.10.2017.
- [13] <http://www.slownik.pwn.pl> – accessed on 03.10.2017.