Preface

Special Issue on Digital Transformation Environment for Education in the Space of CogInfoCom

This special issue brings together papers in the field of digital education and CogInfoCom based LearnAbility including education through online collaborative systems and virtual reality solutions, project- based education and investigating capabilities for learning through modern informatics based education. This is an interdisciplinary research field and fits well in the topic of Cognitive Infocommunication. The key concepts behind CogInfoCom and its application in digital education and learnability is that humans and ICT are becoming entangled at various levels, as a result of which new forms of blended cognitive learning capabilities are appearing. This special issue presents various new results on this scientific disciplina in the following papers:

1) Enhancing Higher Education Student Class Attendance through Gamification

This paper presents an electronic system for tracking students' attendance. "BeHere" was implemented at Subotica Tech – College of Applied Sciences, introducing gamification elements into class attendance tracking. Given that the first year of their studies in higher education is the most crucial time period, it is vital that students are motivated to attend classes regularly. Class attendance is frequently seen as the prime marker of students' persistence: lower attendance indicates a higher risk of dropout. The gamification module of the system is used to improve student engagement, motivation, attendance, and academic performance. Based on the research results, it is evident that the tested gamification module motivated students to attended classes more regularly during the 2018/19 school year as compared with the previous year.

2) Analyzing the spatial skills of university students with a virtual reality application using a desktop display and the Gear VR

This paper presents the analyzed results of a virtual reality application which allows to measure spatial skills of the users. The application contains mental rotation tests of three types and can be used on a computer with desktop displays and on Android with the Gear VR device. The authors measured the spatial ability of 61 students with the Gear VR and of 240 students with a desktop display. By investigating the correct answer ratios, comparisons were done between the age, the gender, the primary hand, what the studends are majoring in, moreover the display devices. Out of the two devices, the Gear VR significantly improved on the performance of female students, left-handed students, older students and made the purdue spatial visualization test easier.

3) Evaluation of Eye-Movement Metrics in a Software Debbuging Task using GP3 Eye Tracker

Teaching different programming subjects is an increasing challenge nowadays as because of growing user demands, the latest paradigms and technologies must be taught. Students in higher education now are of the age who were born into the digital world; however, the success of fulfilling programming courses is lagging behind. Human-computer interface-based research has emerged in numerous fields of science recently, which could lead to the revolutionising of education. These interfaces could also help professors as a support system in transferring knowledge in a more efficient way besides supporting students acquiring adequate home learning methods. In this study, the applicability of eye movement tracking systems in respect of a programming task is examined, in which during the exploration and correction of the errors of an incorrectly functioning algorithm, the eye movement parameters are observed, recorded and evaluated. The test subjects participating in the research were divided into two groups according to some of their characteristic parameters, where the first group during debugging rather applied minor modifications and the more common technique of compile and run, which otherwise is also the most characteristic feature of students studying programming, while the members of the other group increased emphasis on analysing. In the statistic evaluation of the research, the parameters characteristic of the eye movement tracking of the two groups, as well as the efficiency of these groups were analysed. Based on the results, regarding the number of fixations, a significant difference could be shown between the two groups, while concerning the duration of fixation and the saccade length, the difference shown was infinitesimal.

4) Quantitative Analysis of Relationship Between Visual Attention and Eye-Hand Coordination

In perception and activity tasks, continuous visual tracking of the performed activity requires continuous eye motion. Besides writing and reading, the cooperative work of eyes and hands is a key factor when drawing and at certain motions (e.g. ball catching or throwing); during the exact execution of motions, eye-hand coordination has the utmost importance. The development of eye-hand coordination plays a key role in education too, regarding several subjects, i.e. writing, drawing, technique and lifestyle, and of course, at complex motion sequences. Modern ICT tools play an even more significant role in supporting education, where human-computer interfaces similar to the systems introduced in this paper are very significant. In this paper, by analysing certain features describing computer mouse cursor motion, examined during the execution of the Trail Making Task, what correlation is there between visual attention and eye-hand coordination. Based on the statistical correlation analysis results of data, it was determined, that the fixation parameters of eye and hand motion are in negative correlation with visual attention, while the distance between the look and the mouse cursor's motion are not correlated to each other.

5) E-learning spaces to empower students collaborative work serving individual goals

Innovation has an impact on the modern society, so it appears as a demand of the learning society in the educational process. However, there are many other factors that need to be taken into account in supporting an individual's success in designing and implementing a learning process, not just technological change. As opportunities are multiplied, technological support for collaborative work is becoming increasingly demanding to effectively utilization these opportunities in everyday student work. The aim of higher education is to support student success. The continuous adaptation of educational environment to student needs is an important element of this need.

6) The correlations between health behaviors and the use of health-preserving mobile applications in young adults

Individuals' lifestyles manifest themselves in daily activities that can have effects that are a health preserving, preventive or risk-enhancing, in terms of health. Some of them are as simple everyday activities, as eating, exercising or smoking, which are closely related to health without being specifically viewed as health-related behaviors. In the case of university-age young people, a similar activity that affects health is the use of smart devices. Like any other factor, this can also have both positive and negative impacts on health.

In this study, we looked at the health status of university-age young people, as well as their habits in using smart applications. The results have shown that the health of university students studying in Serbia and Hungary is satisfactory in several respects. In addition, several correlations can be seen between their general well-being, their excercise and eating habits, as well as their use of smart devices, applications, more specifically, applications aimed at health-care.

7) Educational tool for testing emotions recognition abilities in adolescents

Recognition of facial expressions is one of the basic skills used to understand the feelings and intentions of others and it represent a crucial ability for establishing interpersonal connections in life. Previous studies have shown that the ability to recognize emotions, the speed and accuracy, with which individuals process emotions, appears to develop through adolescence before reaching its peak in adulthood. Individuals with autism spectrum disorder (ASD) show reduced attention to faces and facial expressions and they have difficulties in identifying emotions. Our goal was to investigate the effectiveness of a technology based educational tool for assessing emotion recognition skills in individuals with ASD and typical developing children. 51 children aged between 12 and 14 year were enrolled in our study, out of which 11 have a diagnosis of ASD. The results of our study show that adolescents perceive differently emotions depending on the type of stimuli that we use and on their ages.

8) Mathability and Creative Problem Solving in the MaTech Math Competition

The Klebelsberg Center and the University of Dunaújváros as a professional partner organized the national MaTech math competition for the second time in 2019,. The main goal of this competition is to develop creativity, creative problem solving, teamwork, and apply of digital knowledge in real mathematical problems when the mathematical capabilities co-evolving with human-ICT systems. The article presents an analysis to identify the characteristics of the mathematical knowledge, and its relationship with skills of creative presentation and performance.

9) Advanced assistive technologies for elderly people: A psychological perspective on seniors' needs and preferences (part A.)

This paper provides an overview of the literature about seniors' psychological perspective in exploiting assistive robots and embodied conversational agents. The main theoretical models devoted to assess user's technology acceptance are briefly reviewed along with a description of the main factors empirically found to be positively/negatively associated with seniors' acceptance of them. Special attention is reserved to barriers generated by seniors' representations of social assistive technologies such as a stigma and threat to their autonomy, infantilization, privacy interferences, fear of dehumanization, and isolation.

10) Putting the Human Back in the Loop: A Study in Human-Machine Cooperative Learning

This paper introduces a novel approach to human-machine collaborative learning that allows for the chronically missing human learnability in the context of supervised machine learning. The basic tenet of this approach is the refinement of a human designed software model through the iterative learning loop. Each iteration of the loop consists of two phases: (i) automatic data-driven parameter adjustment, performed by means of stochastic greedy local search, and (ii) human-driven model adjustment based on insights gained in the previous phase. The proposed approach is demonstrated through a real-life study of automatic electricity meter reading in the presence of noise. Thus, a cognitively-inspired non-connectionist approach to digit detection and recognition is introduced, which is subject to refinement through the iterative process of human-machine cooperation. The evaluation of the prototype system is reported.

11) Movement pattern recognition in physical rehabilitation - cognitive motivation based IT method and algorithms

In this paper, a solution is presented to support both existing and future movement rehabilitation applications. The presented method combines the advantages of human computer interaction based movement therapy with the cognitive property of intelligent decision making systems. With this solution, therapy could be fully adapted to the needs of the patients and conditions while maintaining a sense of success in them, thereby motivating them. In our modern digital age, the development of HCI interfaces walk together with the growing of user needs for them. The available technologies have limitations, which can reduce the effectiveness of modern input devices, such as the Kinect sensor or any other similar sensors. In this article, multiple newly developed and modified methods are introduced with the aim to overcome these limitations. This methods can fully adapt the movement pattern recognition to the users' skills. The main goals are to apply this method in movement rehabilitation, where the supervisor, therapist can personalize the rehabilitation exercises due to the Distance Vector Based Gesture Recognition (DVGR), Reference Distance Based Synchronous/Asynchronous Movement Recognition (RDSMR/RDAMR) and the Real-Time Adaptive Movement Pattern Classification (RAMPC) methods.

12) An architectural approach to Cognitive Information System

The fast changes in information technology and business needs led to the evolution and development of Cognitive Information Systems (CIS). There have been few pieces of research on the general model for the analysis and design of CIS. This paper attempts to create a design scheme for incorporating the various model for CISs and Understanding-based management systems (UBMSS). The components that have been examined create elements of CIS analysis and design, however there were not described as modeling element and not described as an enabling tool to create a consistent and integrated system The most significant components for modeling are: semi-structured documents, business processes, constituents of knowledge management, the enterprise and, the information architecture including self-directing software components – Artificial Intelligence (AI) – that yield function. For CIS modeling the above-mentioned elements were combined into a unified framework that follows the object-oriented paradigm and architecture approaches. The aim of the research to describe a framework that presents an overarching model and assists our understanding of properties of CIS and UBMSS for being able to formulate a practical development method for CIS and cognitive management systems.

13) Experiencing the Sense of Presence in an Educational Desktop Virtual Reality

This study examines the sense of presence in MaxWhere desktop virtual reality. Thirty-one people participated in the research. The participants spend about fifteen minutes in the virtual environment. For measuring presence, the Igroup Presence Questionnaire (IPQ) was used. The results showed that more automatic navigation positively relates to spatial presence. This research also measured the participants' level of experience with the VR software. A significant difference was found in the spatial presence and experienced realism: the more experienced users gave higher ratings on both subscales. At the same time, the involvement and the general presence scores were similar in the two groups, which is advantageous in education as the presence is positively related to the learning outcome.

György Molnár

Guest Editor

Enhancing Higher Education Student Class Attendance through Gamification

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Abstract: This paper presents an electronic system for tracking students' attendance. "BeHere" was implemented at Subotica Tech – College of Applied Sciences, introducing gamification elements into class attendance tracking. Given that the first year of their studies in higher education is the most crucial time period, it is vital that students are motivated to attend classes regularly. Class attendance is frequently seen as the prime marker of students' persistence: lower attendance indicates a higher risk of dropout. The gamification module of the system is used to improve student engagement, motivation, attendance, and academic performance. Based on the research results, it is evident that the tested gamification module motivated students to attend classes more regularly during the 2018/19 school year as compared with the previous year.

Keywords: higher education; class attendance; gamification

1 Introduction

Setting out on an academic career poses a serious challenge for students, especially considering the significant changes from secondary school to university [1]. Their adaptation to the novel circumstances in the first year of higher education is vital [2]. Class attendance is frequently seen as the prime marker of students' persistence and results, while absenteeism is taken as an indicator of the risk of dropout [3, 4]. In this regard, according to [5], there is a great need for motivating students through "an ethos of attendance" as a means of integrating first-year students into academia.

Bruinsma and Jansen stated [6], “the first year is especially important as it serves as an orientation to the remainder of the study and selects those students who are willing to persist”.

There is a wide spectrum of factors influencing the students’ successful adaption to the university lifestyle and their academic achievement during the first two semesters. On the one hand, factors such as the individual student’s age, gender, motivation, and personality, as well as previous (secondary school) performance and efficient study techniques must be taken into consideration. On the other hand, academic aspects including the study programme structure, curriculum design, educational environment, integration activities and social inclusion must also be taken into account [7].

Numerous studies have been conducted into this issue and the central conclusion is that there is a considerable correlation between regular attendance and study results [4, 8, 9]. Halpern [10] explored the relationship between going to classes and passing exams using correlation analysis and determined that a significant moderately positive relationship exists ($r=0.50$, $p<0.001$). Further, Halpern examined whether or not the effect of attendance on academic achievement is causal by applying regression analysis. In Halpern’s view attendance has a significant positive effect ($r=0.40$, $p<0.001$).

There are also, however, authors who express their doubts regarding how attendance will affect the study results. To name just one example, Eisen et al. [11] studied the issue of the importance of attendance versus academic performance among second-year medical students. Based on their results they deduced that not going to active and engaging lectures did not negatively affect the results. In order for informed policy decisions to be made, there is a need for a close examination of the effect of attendance. The debate mostly revolves around whether or not it is the task of the higher education institutions to regulate attendance, e.g. by defining minimum attendance requirements. Several studies highlighted that students may not oppose interventions; in fact, they are likely to see these regulations as indications of care and paying attention to the university’s side [12]. However, certain authors may not agree. St. Clair [13] offered arguments against compulsory attendance, her reasoning being that the currently offered studies do not provide enough justification for such policies. Further, she argues that other, also significant factors influencing study success are thereby disregarded. The goal, in her view, is that students should wish to attend, instead of forcing them to sit in classes through stark regulations. Students should feel being in control, which would, in turn, stimulate them to attend regularly.

Educators still, by and large, expect their students to be present in class. The general assumption is that students will fail to make advancements in knowledge acquisition and comprehension of the study material if they are not in the class so as to enjoy the classroom experience. However, it must be taken into consideration that those young people studying engineering technologies today have grown up in a starkly different learning environment if compared with the classroom of two decades ago. The way they access information and use digital media means that the students have almost instant access via the Internet. The question arises whether or not students will react to this greater connectivity in the same way as to the "older" teaching methods. Modern technology enables current students to learn, access information and interact with their peers even if they do not share the same physical space or visit the library in person. In short, the students of today simply do not have the same need to actually be sitting in their classes just so they could be successful.

Consequently, one may ask why it is that, given access to all digital learning resources, students are still 'tied' to the classroom? In order to be able to answer this question, it must be acknowledged that apart from an altered learning environment, today's engineering students need to gain new technical skills in order to hold successful jobs in the engineering field. Today's tasks require technical engineers to have technical skills and problem-solving skills, as well as communication skills, critical thinking and commitment skills. These skills can only be acquired within the classroom, in active learning environments such as project or problem-based learning.

2 Motivation through Gamification

This section highlights the motivational options which help in stimulating students to spend more time voluntarily in their classes and actively participate in their education. At Subotica Tech – College of Applied Sciences, the lecturers take different approaches in order to reward the students' continued attendance. The main approach is that students' absence has to have negative consequences. The class requirements do not include 'rewards' for actually attending and actively participating, only 'punishment' for missing the classes. Some professors believe that it is the students' responsibility whether or not they wish to attend lectures. These educators do not track student presence, the class requirements also do not indicate any negative consequences for either attending or missing classes.

If one feels 'motivated' it refers to the inherent urge to take action. Thus, if a person feels no stimulation towards taking action, they are likely to be seen as 'unmotivated'. The greater the student's motivation towards learning, the greater the likelihood that the student will engage in classes, which also means that the student has a greater chance of acquiring new knowledge.

People experience various types of motivation, while there are also different levels and orientations of these motivations. For instance, a given student may feel exceedingly stimulated to write homework simply because he or she is curious and interested. However, this motivation may also be due to their drive to prove themselves to their teacher or parent. Another form of motivation may be the fact that the student is aware of the potential usefulness or value of the new skills to be learned.

In Self-Determination Theory (STD) Deci and Ryan presented a great number of motivations driving behaviour and performance [14]. For the purposes of this study, the present authors have use STD's elucidation of motivation processes to build our own system. STD define the continuum of four types of motivations (Figure 1).

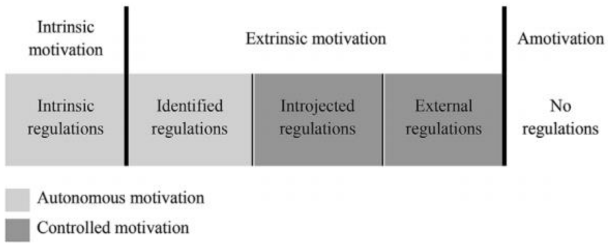

Figure 1
Types of motivation

Intrinsic motivation is, as the definition suggests, "doing something because it is inherently interesting or enjoyable", while extrinsic motivation means "doing something because it leads to a separable outcome".

Educators have become more and more aware of the significance of intrinsic motivation [15]. Given that intrinsic motivation is likely to lead to high-quality learning and creativity, it is vital for those factors and forces that foster as opposed to hampering it.

Extrinsic motivation, though, is no less crucial and must, therefore, be thoroughly understood by educators. Not all lectures and activities are instantly seen as 'interesting' or 'enjoyable', so students must be enticed and engaged by various the extrinsic motivation techniques [16, 17].

Gamification is defined as using game elements and game design techniques in non-game contexts. The overall goal is to integrate intrinsic motivation with extrinsic motivation so as to trigger students' engagement and motivation to participate actively [18]. Numerous studies highlighted the positive learning outcomes of using gamification [19], though, there are also papers that presented mixed results or even negative effects [20].

The gamification module created by the author's implements points, badges, and a leader-board (PBL) as game elements in the rewarding system. The aim is for the student to receive feedback from the educator in the form of these elements, which will make them more aware of their advancement and active participation in their own learning process. The PBL system also serves as a method of comparison for each other's achievement. The following section outlines the application of gamification in the system tracking class attendance.

3 Presentation of Electronic System for Tracking Attendance

Tracking attendance is a crucial activity on all levels of educational institutions, from elementary school to university. The teacher needs to be able to trace the classroom presence as well as activities of any given student. If a particular class is attended by a large number of students, the teacher would generally resort to the age-old method of roll call and marking attendance on paper. However, this is both tedious and time-consuming, thus a novel method of tracking attendance has to be introduced.

In this section, we present an electronic system with the task to automate the tracking of class attendance. Automation is vital since it ensures the fact and efficient task performance. The task itself is anything but trivial. The teacher spends (in fact, 'loses') a considerable amount of valuable teaching time on recording class presence. After having recorded who is present in a given class, the teacher must then archive the collected data along with the other class information. Without digitalization, trying to trace the overall class activity of a single student becomes quite a challenge, and manual data input is even more time-consuming. The time needed for tracking and evaluating class attendance only increases with the rising number of students in a group or on a specific course.

Electronic tracking of class attendance enables the teacher to quickly generate an attendance report for an individual student on a given course. The data is stored in a database, which can be accessed by teachers, institutional management, as well as in certain cases the students themselves. The teacher may use the gathered data to influence the educational process.

Management of a given educational institution may analyze the data on class attendance and make the following deductions:

- which course has an attendance problem – a piece of information that may be in relation to the quality evaluation of the given course;
- the rate of student number fluctuation;
- whether or not the classes are held as indicated in the official class time table.

Generating an attendance report enables the teachers and/or management to quickly find ways to identify and remove the causes for low attendance. Subotica Tech – College of Applied Sciences almost regularly experiences a dissipation rate of about 25%, with a quarter of its students 'disappearing' by the start of the January exam period. There is a considerable need for a system that could offer daily feedback on student attendance, i.e. absenteeism, so as to detect those students who are likely to constitute the 25%, and identify the causes for the 'disappearance'. One of these causes insufficient pre-knowledge in students, which makes it difficult for them to follow the classes. A further cause is that college students come from vastly different educational backgrounds, from a wide range of secondary schools that may not be compatible with the technical profile of the College. Thus, it may happen, for instance, that high school students from the Medical secondary school or Chemical Vocational school actually enroll in Subotica Tech, but lack satisfactory background knowledge in the technical-technological field studies to be able to successfully complete this technical college. All parties would benefit from a system that would allow the identification of the missing background knowledge and opportunity through, e.g. short courses to attain the level of the general class so as to include these students, too, in the successful educational process.

3.1 Hardware Modul

Prior to realizing this project of an electronic attendance tracking system, a number of similar systems were analyzed. This paragraph details the features and possibilities offered by these analyzed systems, as well as the method of identification they use. At Texas State University a web application is implemented for displaying a given individual's campus activities. Identification happens via ID card and card reader [21]. The second example is the 'Creatrix Campus Attendance Management System', which includes not only student identification in the different classrooms where they listen to lectures (and engage in different learning activities), but also analyzes the movements and activities of an individual student. Based on the pattern of activities, i.e. times of absence, the system automatically suggests various measures to improve the situation, setting attainable goals for those students, all aimed at motivating the individual to attend classes regularly [22]. Northern Arizona University uses an RFID method for student identification. The ID process happens via card readers that are installed in the lecture halls where the students attend the lectures and in locations where they engage in other educational activities (classrooms, computer science laboratories, etc.). This enables fast and efficient identification even for large numbers of students [23].

The implementation of the previously described systems incurs considerable costs. The proper operation of the system requires the installation of card readers in all classrooms, distribution of cards among students and the creation of a central information system that stores and displays information (i.e. server with a database). The overall cost of implementing this tracking system at Northern Arizona University was close to $ 85.000. During the design process of the class attendance tracking system for students at Subotica Tech, the following requirements needed to be met: all the main functions had to be included - tracking attendance, recording and displaying information on the presence, moreover, the system needed to be inexpensive both in terms of realization and maintenance. This goal was achieved in the following way according to the scheme on Figure 2:

- attendance identification happens via smartphone, thereby eliminating the costs of ID, NFC or RFID cards;
- identification is confirmed by a microprocessor system whose cost does not exceed €30. The device is small, easy to carry into class and is functional in classrooms without Internet access, as well;
- free software solutions were found for the webserver and database server.

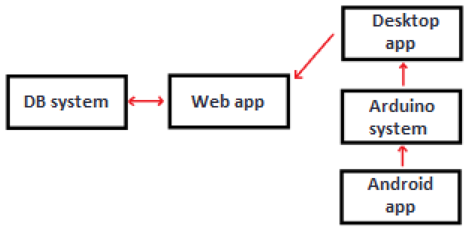

Figure 2
Block scheme of the system

The electronic class attendance tracking system is composed of several units:

Android application. The student can log in via an Android application for a mobile phone, which identifies him or her. Identification is easy, it is a simple click on a button. As soon as the application sends the student's data to the Arduino system, the user receives confirmation on successful identification. The application only sends basic information, most importantly, the student's index number. Detailed user information of the student to be identified is entered during the primary installation of the application and cannot be altered later (Figure 3).

Arduino platform. The characteristics of the Arduino NANO microprocessor platform are as follows: 12 digital inputs/outputs D2-D13; 8 analogue inputs A0 ~ A7; 1 TTL serial port - RX / TX; 6 PWM port; uses Atmel Atmega328P-AU microcontroller (Figure 2). The Arduino and the mobile application communicate via Bluetooth connection using a HC-05 module (Figure 3).

Desktop application for controlling Arduino via microprocessor (Figure 4). An application has to be installed on the teacher's PC which can control the Arduino platform. The process of attendance tracking is described below.

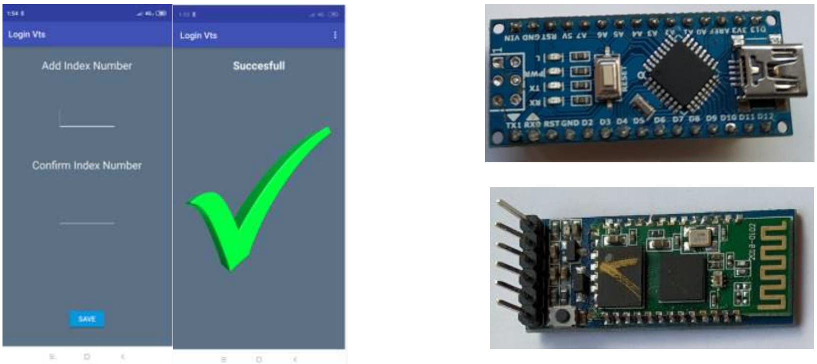

Figure 3
Mobil application interface and Arduino and Bluetooth module

The Arduino microprocessor is connected to the teacher's PC through one of the USB ports, and the teacher runs the application, enters the relevant data (select teacher's name and course title), then the PC initiates the connection to the Arduino. After clicking on the Start button, triggers the process of tracking student attendance. The system then makes connections with all the applications running on the students' mobile devices until the teacher clicks on the Stop button.

The students run the application on their own mobile devices and by clicking on the button, start log on to the system. Given that Bluetooth connection can only happen between the two devices at the same time, the link between student mobile devices and the Arduino occurs sequentially. The time required for identifying each student is approximately 1 second. Prior to the identification process, it is necessary to pair the students' mobile devices with the Arduino system. This is a short procedure that is performed only once, at the start of the semester.

Once the teacher's PC successfully receives the data, the students' names are listed. By clicking Stop, the teacher discontinues the process of tracking attendance. By clicking Upload, the collected data is sent to the server application. The desktop application is both fast and easy to handle.

Figure 4
Desktop application

The system is capable of identifying up to 60 students (i.e. their devices) in one minute if located within a radius of 10 meters. The relatively limited range of the Bluetooth connection prevents students from cheating the system by trying to confirm their presence from any other classroom except where the class is held, even within the college building. Due to privacy issues, the students' names are presented here in strike-through marked with a yellow line.

Web application. The server application's main task is to receive and store data in the database. The application has access restriction, so only the registered teachers can log on to the system. After the login, the teacher has access to data related to his/her classes. The teacher can select which class attendance data to be displayed. The data is presented in a table, where the rows signify the students, while the columns are the weeks. At Subotica-Tech one semester is composed of 15 weeks. Since every course can have either a lecture or exercise part or in general, both, this means that the teacher can register attendance at one course for one student a maximum of 30 times (twice a week). The next figure (Figure 5) shows the table for one class with the students' names and their attendance in weeks.

Figure 5
Students' attendance in weeks

The table shows which week the student was present in class (blue rectangles marked with '1') and which week the given student missed this specific class (red rectangle marked with '0'). With this "table view," the teacher immediately has an overview of how many students attend a specific class, and which weeks they attended the class.

This table is also used for the manual recording of attendance registration: by clicking on the red rectangle it becomes blue. This option is important because there are cases when the student in unable to register using his/her phone, for example, if they forgot to bring their mobile phone to the school, or if the phone has no Android OS, etc. This is also the page where the teacher can assign badges to the student.

3.2 Gamification Module

The suggested class attendance tracking system automates the process which teachers have so far been handling manually as an integral part of their teaching activities.

Gamification, and it's awarding nature is just one of the methods used in trying to motivate students to be more active in their own educational process. The idea that was realized in this project was to create a so-called 'high score list' (or leader-board) of ranking the 'best' students. The list is formed based on the following criteria:

- Number of class attendances on courses in a given academic year for a specific student;
- Points to be gained through extra tasks that the teacher deems worth awarding points for.

The 'high score list' contains the student's name, the overall points collected in the two ways described above (see Figure 6). The badges form a visualization of the points given by the teachers for various activities completed by the student. The system currently contains nine badges. Each badge has its own defined value and graphical representation. The first badge is the 'bronze badge' without any stars. The next two are also 'bronze' ones, yet with stars added. This is followed by the 'silver badge' and 'gold badge' in the same distribution.

Figure 6
"High Score" list based on the collected points

4 Research

The basic hypothesis is that applying gamification increases students' motivation to attend classes. Accordingly, the aim is to test the following hypothesis:

H1: Gamification will increase students' attendance to classes.

In addition to this main hypothesis, the following hypotheses were also stated:

H2: The leader-board is a motivating element for students.

H3: Badges awarded for active participation in classes are seen as a motivating element.

Hypothesis H1 will be tested by analyzing the data of students' regular class attendance when their attendance was recorded using the "BeHere" system and when their attendance was checked in the traditional way (calling out students by name or collecting students' signatures).

As stated earlier, Subotica Tech uses the "BeHere" system to record students' class attendance. It was initially used in the academic year 2018/19. The collected data served as the basis for testing the hypothesis H1.

The attendance data forming the basis for analysis was collected among the first-year students in the autumn and spring semesters of two academic years, 2017/18 and 2018/19. In both autumn semesters, the course whose attendance was tracked was the English language, while in the spring semesters the platform of tracking attendance was the informatics course Object-oriented programming. In the first year of testing, during the academic year 2017/18, attendance tracking was performed in the classic form, by the teacher, through roll call or having the students sign an attendance sheet. These students were the control group. In the second year of the experiment, in 2018/19, attendance tracking was performed using the "BeHere" system with its integrated gamification elements. These students formed the experimental group.

The higher education system in Serbia defines the semester as a study period of 15 weeks. Based on this, class attendance is recorded both for lectures and practices, thus for a given course, the student can ideally be recorded twice a week as having attended classes. This leads to an overall number of 30 times during one semester, for one course, when the student could be recorded as attending classes.

The following distribution was drawn up based on how many times they attended the classes:

- Group I – students missed 1/3 or less of all the classes (1/3 of the 30 classes in total, including both lectures and practices) during the semester,
- Group II – students missed between 1/3 and 2/3 of the classes,
- Group III – students missed more than 2/3 of the overall number of classes.

During the academic year 2017/18, the total number of students whose attendance was tracked was 358 (N=196 for the course English language and N=162 for Object-oriented programming). The total number of students whose class attendance was tracked in 2018/19 was 340 (N=185 for English language and N=165 for OOP).

Only the students meeting one of the following criteria were included in the process of analysis: a) students who attended at least one lecture, b) attended at least one practice, or c) handed in at least one homework project, or taken one test during the term. Taking all these into consideration, the distribution of the overall student participant number was:

- during the academic year 2017/18, there were overall 288 students, 14% of them female and 86% male (N=160 for English language and N=128 for OOP)
- during the academic year 2018/19, there were overall 282 students, 17% of them female and 83% male (N=150 for English language and N=132 for OOP)

Table 1 presents the distribution of the number of participants based on how often the students attended classes, categorized into three groups as described above:

Table 1
The distribution of the number of participants based on how often the students attended classes

	English language		OOP	
	Control group	Experimental group	Control group	Experimental group
x*<1/3	57	65	45	55
1/3<x<2/3	66	60	54	60
x>2/3	37	25	29	17
	160	150	128	132

*where x is the number of absences

One of the requirements during the semester is, in fact, class attendance, for which students are awarded a set number of points. For the courses in question, English language, and Object-oriented programming, the course coordinators opted not to award any points for regular class attendance.

An independent-samples t-test was conducted to compare the number of absences for the control and experimental group based on the number of absences for the course English language and Object-oriented programming. The results for each of the three groups are shown in Table 2, 3 and 4 for the course English language and for the Object -oriented programming are shown in Table 5, 6 and 7.

Table 2
Group I statistics for absenteeism less than 1/3 of the total number of the classes for the course English language

	N	Mean	Std. Deviation	Variance
Control group	57	5.9123	2.9897	8.9386
Experimental group	69	4.8308	2.7532	7.5803
t	**2.0795**			
Degrees of freedom	120			
Critical value	**1.98**			

The experimental group students (M=4.8308, SD=2.7532) had fewer absences than the students from the control group (M=5.9123, SD=2.9897). The means of control and experimental group are significantly different at $p < 0.05$.

Table 3
Group II statistics for absenteeism greater than 1/3 and less than 2/3 of the total number of the classes for the course English language

	N	Mean	Std. Deviation	Variance
Control group	66	16.0303	2.8337	8.0298
Experimental group	60	14.9333	2.887	8.3345
t	**2.1509**			
Degrees of freedom	124			
Critical value	**1.98**			

The experimental group students (M=14.93, SD=2.887) had fewer absences than the students from the control group (M=16.0303, SD=2.8337). The means of control and experimental group are significantly different at $p < 0.05$.

Table 4
Group II statistics for absenteeism greater than 2/3 of the total number of the classes for the course English language

	N	Mean	Std. Deviation	Variance
Control group	37	25.8378	2.5551	6.5285
Experimental group	25	24.48	2.2383	5.01
t	**2.1554**			
Degrees of freedom	60			
Critical value	**2**			

The experimental group students (M=24.48, SD=2.2383) had fewer absences than the students from the control group (M=25.8378, SD=2.5551). The means of control and experimental group are significantly different at $p < 0.05$.

Table 5
Group I statistics for absenteeism less than 1/3 of the total number of the classes for the course OOP

	N	Mean	Std. Deviation	Variance
Control group	45	5.8889	3.0616	9.3737
Experimental group	55	4.6182	2.7182	7.3886
t	**2.1969**			
Degrees of freedom	98			
Critical value	**1.987**			

The experimental group students (M=4.6182, SD=2.7182) had fewer absences than the students from the control group (M=5.8889, SD=3.0616). The means of control and experimental group are significantly different at $p < 0.05$.

Table 6
Group II statistics for absenteeism greater than 2/3 of the total number of the classes for the course OOP

	N	Mean	Std. Deviation	Variance
Control group	54	16.2963	2.717	7.3823
Experimental group	60	14.9333	2.887	8.3345
t	**2.5878**			
Degrees of freedom	112			
Critical value	**1.984**			

The experimental group students (M=14.9333, SD=2.887) had fewer absences than the students from the control group (M=16.2963, SD=2.717). The means of control and experimental group are significantly different at $p < 0.05$.

Table 7
Group II statistics for absenteeism greater than 2/3 of the total number of the classes for the course OOP

	N	Mean	Std. Deviation	Variance
Control group	29	25.8866	2.4105	5.8103
Experimental group	17	24.3529	2.2344	4.9927
t	**2.1522**			
Degrees of freedom	44			
Critical value	**2.015**			

The experimental group students (M=24.3529, SD=2.2344) had fewer absences than the students from the control group (M=25.8866, SD=2.4105). The means of control and experimental group are significantly different at $p < 0.05$.

Based on the results of the analysis the hypothesis H1 is confirmed with a certainty of 95% and a risk of 5%, that there is a statistically significant difference between the results of the control and experimental group, i.e. that gamification increased students' attendance to classes.

The experimental group was asked to complete a survey on gamification as a motivating factor in regular class attendance. We used Feedier to design and distribute the survey. The participants were informed about (a) the aim of the study, (b) the expected workload and (c) the need to have at least a moderate level of knowledge of the mentioned service. Also, potential respondents were assured of the anonymity and confidentiality of their responses. Attempts to complete the survey more than once on the same device were blocked.

The survey was distributed among all students of the experimental group (N=282), 220 of whom managed to complete the survey in full (male: 85%; female: 15%; age: M=20). The survey was composed using the guidelines found at [21]. The survey results are presented in Table 8.

Table 8

Numerical feedback answers about the achievement badges (N=282). (1=completely disagree, 2=somewhat disagree, 3=cannot say, 4=somewhat agree, 5=completely agree)

Feedback item	1	2	3	4	5
I found the badges motivating.	6%	10%	10%	**46%**	28%
Badges were disturbing me in my studying.	**60%**	20%	10%	8%	2%
Trying to achieve badges affected my behaviour.	1%	18%	10%	**40%**	31%
The visual look of the badges was good.	1%	1%	30%	**42%**	26%
I was satisfied with the criteria for awarding badges.	1%	3%	15%	**48%**	33%
I think that badges motivated me throughout the semester.	2%	3%	20%	25%	**50%**

Based on the survey filled in by the students of the experimental group, it can be concluded that for most students, the badges had a motivating role in attending classes as regularly as possible. The majority of the students responded that they found the badges motivating and that they had an effect on their behaviour. Furthermore, the majority was satisfied with the criteria and visual appearance. Moreover, only a small minority of 10% reported that badges disturbed their work.

Students were given the opportunity to comment on the use of badges. The students' comments mostly revolved around the fact that collecting badges was like playing a game for them and that the desire to unlock a new badge was strong enough to motivate them to attend a class (especially when they needed only a few more points until the next badge). However, there were also comments stating that while at the beginning it was interesting to collect points and receive badges, it became tedious, they became quickly bored and no longer cared about attending classes in order to progress in winning new badges.

For a certain number of students, the badges held no significance and did not motivate them to attend classes regularly. The comments of this group of students highlighted that they would definitely attend classes because they were interested in the subject, regardless of whether or not they received badges regularly. Some of them commented that it was too childish to collect badges, that they came to classes when it was convenient for them and that they were not too concerned about winning some badges or not.

A certain number of the students believed that it would be much better, in fact, more motivating if they were given specific rewards in addition to badges, e.g. in the form of bonus points that they could redeem at a mid-term test or exam. Some of the students belonging to the second and third groups by the number of absences from classes were satisfied with the possibility that points could be obtained through badges which improved their position on the leader-board.

Students were pleased to be able to trace the performance of their peers through the badges and to compare themselves to the others. There were further suggestions to consider enabling the students to share their badge status on social networks, primarily to show off to their peers, or “tease” those who were ranked lower in the number of collected badges. Students also voiced their objection because it was not possible to pass the badges into the next academic year.

The students' views about the leader-board were very polarized. As a motivational element, the leader-board either had a weak effect or a highly positive effect, which is related to the personal preferences of the students. The students who have a competitive nature wanted their name to be ranked highest possible on the leader-board. For them, progress in the rankings during the semester was a motivating factor, they aimed for the top of the list. The second group consisted of students who did not care about ranking. Their views indicated the importance of the user's internal motivation for a successful outcome.

Table 9

Numerical feedback answers about the leader-board (N=282). (1=completely disagree, 2=somewhat disagree, 3=cannot say, 4=somewhat agree, 5=completely agree)

Feedback item	1	2	3	4	5
The leader-board motivated me to attend classes.	11%	14%	8%	**45%**	22%
The leader-board motivated me to arrive to class on time.	9%	7%	15%	**48%**	21%
I was more motivated to attend classes every week to do well on the leader-board.	6%	11%	18%	**46%**	19%
A high ranking on the leader-board increased my self-confidence.	1%	3%	15%	**56%**	25%
I would find it more motivating if a high ranking on the leader-board were rewarded by the College.	10%	10%	**37%**	33%	10%
I found the use of the leader-board intimidating.	**47%**	31%	12%	8%	2%

Conclusions

Based on the research results, it is evident that students attended classes more regularly during the 2018/19 school year as compared with the students' attendance in the previous year (first year of the experiment). It can, therefore, be stated that gamification motivated students to attend classes as regularly as possible. Students need to be aware that their attendance at lectures and exercises has a purpose, it is not only to satisfy a form. Instead, classes represent a time period that can be spent usefully by acquiring and confirming the knowledge and skills necessary for their success during studies as well as in the jobs they will take after graduation.

The proposed system for tracking class attendance automates, accelerates and digitizes the collected data and is useful for an educational institution and its students, as well. Points of interest include the following:

Through the gamification techniques and elements, apart from educational success (grades), the student is also given an opportunity to show off his or her characteristics, skills, abilities, etc. Gamification as a tool is aimed at motivating the student to actively participate in his or her own educational process.

The field of gamification is new and has yet to be fully researched. Motivation, both intrinsic and extrinsic, is a key factor in the success of students at all stages of their education. There are many motivating methods that could be implemented in education. The proposed system can be crucial in providing and encouraging students' motivation. For example:

- **Give students a sense of control**: this will allow them to define the priorities and to choose how to achieve the goals.

- **Define the objectives**: students always know how to acquire points and be better ranked on the list.

- **Use positive competition**: it can motivate students to try harder, to learn more just to be better ranked from the others.

- **Offer rewards**: through ranking on the leader-board and collecting badges, students get rewards. Those who contribute better, gain reward(s) and better ranking. Encouragement is the best way of motivating!

- **Give students responsibility**: what will be his/her ranking, which badges will stand beside his/her name depends only on how active the student is. The transferred responsibility can motivate the student.

- **Make your classes exciting**: Students must continuously be active or to attend to classes, because he/she will lose the position on the leader-board, or someone else will collect more badges.

- **Make goals high, but attainable**: Every student is aware of the fact that through attendance and contribution in class activities they can achieve a good position on the leader-board.

- **Give feedback**: The points, the badges and the position on the leader-board are the feedback for the student. Through them, the students can see if they are doing well, or if they should try to improve something.

- **Track progress**: The points, the badges and the position on the leader-board present the student's activity in real-time.

- **Make things fun**: collecting badges and points are some kind of play. Competition with colleagues through playing makes this process fun.

- **Provide opportunities for success**: the presented system offers two ways for improving position on the leader-board. Firstly, the student collects points by attending classes. More attendance means more points. For the students who prefer different ways of learning, for example through the Internet, there is an opportunity to earn point simply by being active. This includes participating in competitions or doing extra projects, or by being active in class, the student can compensate for points that were lost by not attending every class.

The presented results and analyzes fits well in the field of CogInfoCom based education [25] and raises many of its applications in a variety of related research such as human-computer interfaces [26] and virtual or augmented reality supported learning [27, 28] or serious games and team based collaborative education [29-32] or cognitive abilities [33-37] for example.

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Analyzing the Spatial Skills of University Students with a Virtual Reality Application using a Desktop Display and the Gear VR

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Abstract: This paper presents the analyzed results of a virtual reality application which allows measuring spatial skills of the users. The application contains mental rotation tests of three types and can be used on a computer with desktop displays and on Android with the Gear VR device. The authors measured the spatial ability of 61 students with the Gear VR and of 240 students with a desktop display. By investigating the correct answer ratios, comparisons were done between the age, the gender, the primary hand, what the students are majoring in, moreover the display devices. The use of the Gear VR significantly improved on the average performance of female students by 18.02%, on left-handed students by 18.66%, on older students by 7.29% and made the purdue spatial visualization test easier by 17.21% compared to the use of a desktop display. These results also strengthen the fact that education has a future in virtual reality.

Keywords: cognitive skills; desktop display; Gear VR; mental rotation test; mental cutting test; purdue spatial visualization test; spatial ability; virtual environments; virtual reality

1 Introduction

Spatial ability is an important skill in the modern world as engineering applications; even jobs require a good use of it. This ability allows the person to understand spatial relations between objects and space. As it is a cognitive ability, it can be measured and improved by solving simple geometric problems. These geometric problems were recreated as tests and they have existed since the last century. These tests are called the Mental Rotation Test (MRT) [1], the Mental Cutting Test (MCT) [1, 2] and the Purdue Spatial Visualization Test (PSVT) [1, 3]. Each test type has a different type of mental rotation.

To this day, these tests mostly exist in paper-based formats. However, humanity is transitioning into a digital age, thus computers are spreading into the field of education: Virtual reality (VR) can positively affect the learning skills of students [4, 5]. Also, with the inception of Cognitive InfoCommunications (CogInfoCom) [6-8], it becomes easier to investigate the relationship of the human, information and communication technologies (ICT) and therefore, new cognitive capabilities can emerge [9].

Normally, the state of the art of improving spatial ability is vast. Sadly, most methods to improve spatial ability only exist in paper-based formats or in reality, but not in VR. There are, however, some exceptions which are digitalized or VR versions of these methods. These exceptions are mentioned in this paper.

The authors of [10] implemented the Paper Folding Test in VR. In [11] they assessed gender differences in mental rotation and the spatial ability of users in VR. Similarly, in [12] they assessed the spatial ability of both males and females in VR and in augmented reality (AR). Both studies concluded that males are better in mental rotation than females in VR and in AR. Also, the latter study suggests that AR could be a good tool for improving spatial ability. In a pilot study in [13], it has been concluded that VR is an effective spatial ability improving tool.

The three newest studies in this field are [14-16]. Similarly to [13], in [14] they concluded that VR is effective for improving spatial ability. In [15], they used the PSVT-rotation (PSVT-R) test and concluded that with VR goggles the users showed a significant improvement over the ones who used a desktop display. The study seen in [16] is not based on these geometric tests, but on navigating in VR. In the study, they concluded that actively navigating in VR can improve the spatial ability of older users.

The authors of this article developed a VR application [17] that contains the MRT, MCT and PSVT tests. This application gathers the data of spatial skills of the users in real-time. After gathering the data, the authors can analyze it. The results of the analysis are presented in this paper.

This paper is structured as the following: In the next section, the authors set up the research questions and hypotheses. Section 3 deals with the methodology used in testing. Section 4 presents the results. In section 5, the hypotheses are accepted or rejected, then the theses are formed. Lastly, conclusions are made.

2 Research Questions and Hypotheses

During the application development phase and before the testing, the authors set up 11 research questions (RQ) and hypotheses (H). The first five are about the tests on the desktop display, the next five are about the tests on the Gear VR, and the last one is about comparing the devices. The RQs are the following:

- RQ1: Which test mode is the easiest and the hardest when using a desktop display?
- RQ2: Is there any difference between the male and female performances using a desktop display?
- RQ3: Does the primary hand of the user influence the results of the tests when using a desktop display?
- RQ4: Does the age of the user affect the results of the tests when using a desktop display?
- RQ5: Does the major of the user affect the results of the tests when using a desktop display?
- RQ6: Which test mode is the easiest and the hardest with the Gear VR?
- RQ7: Is there any difference between the male and female performances on the tests with the Gear VR?
- RQ8: Does the primary hand of the user influence the results of the tests when using the Gear VR?
- RQ9: Does the age of the user affect the results of the tests on the Gear VR?
- RQ10: Does the major of the user affect the results of the tests when using the Gear VR?
- RQ11: With which device do the users achieve better results on the tests?

As the statistical hypothesis testing test the equality, and the alternative hypothesis is the nonequality, the authors formulate the following hypotheses:

- H1: In the case of desktop display, the average rates of correct answers are the same in case of all types of tests, opposite to, they depend on the test type. In case of different values of average rates, are they the same with both display devices? Do the statistical evaluations reflect the subjective opinions of students: “The MCT mode is the hardest and the PSVT mode is the easiest when using a desktop display”.
- H2: The performances of males and females are equal, opposite to males perform better on the tests when using a desktop display.

- H3: The performances of left-handed and right-handed people are equal, opposite to left-handed people perform better on the tests when using a desktop display.
- H4: The performances of older people are equal to younger people, opposite to older people perform better on the tests when using a desktop display.
- H5: The performances of the students with different major are equal, opposite to, they differ when using a desktop display.
- H6: The average rates of correct answers are the same in case of all types of test opposite to they depend on the test type when using the Gear VR. Do the statistical evaluations reflect the subjective opinions of students: "The MCT mode is the hardest and the PSVT mode is the easiest when using the Gear VR".
- H7: The performances of males and females are equal, opposite to males perform better on the tests when using the Gear VR.
- H8: The performances of left-handed and right-handed people are equal, opposite to left-handed people perform better on the tests with the Gear VR.
- H9: The performances of older people are equal to younger people, opposite to older people perform better on the tests with the Gear VR.
- H10: The performances of the students with different major are equal, opposite to, they differ when using the Gear VR.
- H11: The average rates of correct answers are equal if the user uses desktop display and Gear VR, opposite to the users who test with the Gear VR achieve better results.

3 Methodology

An application for the mentioned tests was developed in the Unity game engine (version 2018.3.14f1) at the University of Pannonia during the first half of 2019. It contains the MRT, MCT and PSVT tests, as seen in Figure 1. Each test has ten rounds of questions relating to spatial ability. The application runs on Windows operating systems and on Android due to the Gear VR device, namely the Samsung Galaxy Gear VR SM-R322 with a Galaxy S6 Edge+ smartphone.

The tests were conducted with the application at the University of Pannonia and at the University of Debrecen during September 2019. At the former, 61 students tested the application with the Gear VR device and at the latter, 240 students tested the application with a desktop display device, namely with an LG 20M37A (19,5") display device. Students who tested with the Gear VR consisted of Information Technology (IT) and non-IT students. Those who tested with the desktop display were either Architectural Engineering (AE) or Mechanical Engineering (ME) students.

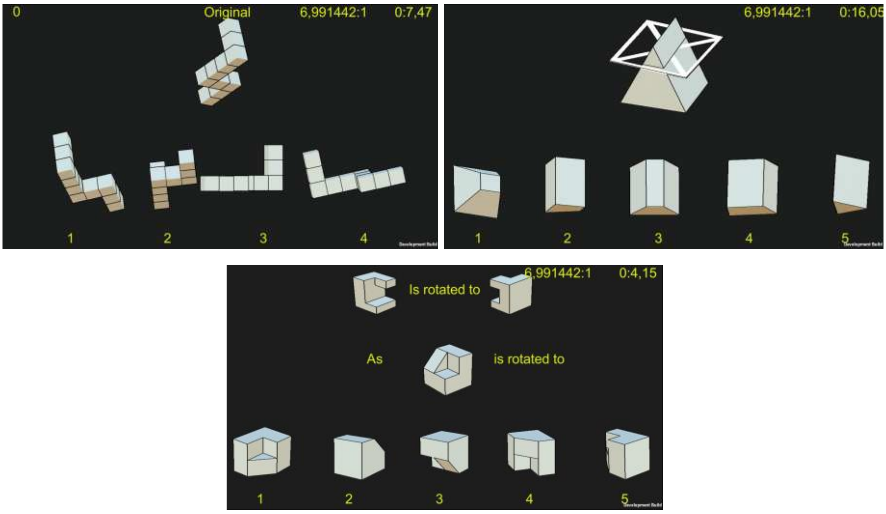

Figure 1

Screenshots of the MRT (left), MCT (right) and PSVT (center) test types

As one Gear VR device was available at the University of Pannonia, the VR testers came in sequential order through three weeks. The number of testers depended on the day, the least number of testers a day was 2 people and the most was 8 people. Testing at the University of Debrecen was different: The testers did the tests in a computer laboratory. There were twenty groups, each around 20 people. Each tester had to do all three types of spatial ability tests: The MRT, MCT and PSVT tests. After all three have been done, each tester had to do each type two more times. One tester lasted approximately 45 minutes.

The application logged the following information into a .csv file:

- The gender of the user, the age of the user, the primary hand of the user, the number of years spent at a university and what the user majored in.
- The test type, the test time, and the number of correct and incorrect answers.
- The application also logs technical information of each test, such as the virtual camera type, field of view, contrast ratio, rotation and whether shadows are turned on or off. This category is not focused on in this paper.

The ratios of the correct answers by the students were investigated. The authors checked the hypotheses of normal (Gauss) distribution by Kolmogorov-Smirnov tests. Then, the authors tested the equality of standard deviations (dispersions) and expectations. For the cases of dispersions, the authors applied F tests, and equality of expectations were checked by t-test or Welch-test [18]. The calculations were carried out by the statistical program package R.

4 Results

In this section, the results of the tests can be seen. The authors divided this section into three subsections: Subsection 4.1 deals with the desktop display results, subsection 4.2 with the Gear VR results, and subsection 4.3 is the comparison between the two devices.

4.1 Desktop Display Results

This subsection deals with desktop display results. Here, five different analyses can be found: The difficulty of the tests, the ratios of correct answers by gender, by primary hand, by age, and by majors.

4.1.1 Difficulty of the Tests

In Tables 1, 2 and 3, statistical data of all test types and even of their difficulties can be seen.

Table 1

Ratios of correct answers by test type with a desktop display

	Students	Min	Max	Average	Dispersion
MRT	240	0.4167	1	0.8041	0.1334
MCT	240	0.1333	0.9667	0.4389	0.154
PSVT	240	0.1333	0.9667	0.6168	0.1932

Table 2

Comparisons of standard deviations of the ratios of correct answers with a desktop display, also showing what is equal (eq)

	MRT			MCT			PSVT		
	Test value	Sign.	Eq.	Trial stat.	Sign.	Eq.	Test value	Sign.	Eq.
MRT	0	1	Yes	0.7503	0.0268	No	0.4764	0	No
MCT	0.7503	0.0268	No	0	1	Yes	0.6349	0.0005	No
PSVT	0.4764	0	No	0.6349	0.0005	No	0	1	Yes

Table 3

Comparisons of averages rates of correct answers with a desktop display, also showing what is equal (eq)

	MRT			MCT			PSVT		
	Test stat.	Sign.	Eq.	Test stat.	Sign.	Eq.	Test stat.	Sign.	Eq.
MRT	0	1	Yes	27.775	0	No	12.358	0	No
MCT	27.775	0	No	0	1	Yes	-11.155	0	No
PSVT	12.358	0	No	-11.155	0	No	0	1	Yes

As can be seen from the Tables 1, 2 and 3, every test type is distinguishable from the others. Also, the MCT test is the hardest type of test. The MRT type is the easiest and the PSVT test stands between MRT and MCT in terms of difficulty.

4.1.2 Comparison of Genders

The authors tested the type of distribution regarding genders. The hypothesis of normal distribution was accepted with p-value = 0.4846 in the case of males and with p-value = 0.9707 in the case of females. Table 4 shows the ratios of correct answers.

Table 4

Ratios of correct answers by gender with a desktop display

	Students	Min	Max	Average	Dispersion
Male	211	0.3083	0.9667	0.6769	0.1172
Female	29	0.4417	0.7833	0.5865	0.0966

The equality of dispersions is accepted with p-value = 0.2213, but the equality of average rates is rejected on the level of significance 0.00004. Thus, the ratio of correct answers is significantly better for males in the case of the desktop display.

4.1.3 Comparison of the Primary Hand of the User

Next, the effect of the primary hand of the users was investigated. The hypothesis of normal distribution was accepted for both primary hands. For right-handed users, it was accepted with p-value = 0.5343 and p-value = 0.9313 for the left-handed users. The ratios of correct answers of users in the case of the desktop display are found in Table 5.

Table 5

Ratios of correct answers by primary hand with a desktop display

	Students	Min	Max	Average	Dispersion
Right-handed	213	0.3083	0.9667	0.6691	0.1176
Left-handed	27	0.4417	0.8833	0.6414	0.1242

The equality of dispersions was accepted with p-value = 0.6567 and the equality of the expected values is also accepted with p-value = 0.2796. Therefore, there is no significant difference between right-handed and left-handed people when using a desktop display.

4.1.4 Comparison of age Groups

Afterward, an age-group analysis was made. The basic data can be seen in Table 6, and the analysis can be seen in Table 7.

Table 6
Statistical data of rates of correct answers by age groups with a desktop display

Age	Students in group	Group average	Group dispersion
17	1	0.666	0
18	33	0.623	0.124
19	89	0.667	0.116
20	75	0.680	0.111
21	29	0.673	0.125
22	6	0.573	0.087
23	2	0.750	0.087
24	2	0.612	0.205
25	1	0.808	0
27	1	0.758	0
32	1	0.866	0

Table 7
Comparing different age groups who used a desktop display

	Group 1	Avg. rate 1	Group 2	Avg. rate 2	p-value	Significant difference
<= 17 & > 17	1	0.6667	239	0.666	0.9277	No
<= 18 & > 18	34	0.6245	206	0.6728	0.0375	Yes
<= 19 & > 19	123	0.6556	117	0.6769	0.1656	No
<= 20 & > 20	198	0.6652	42	0.6696	0.8357	No
<= 21 & > 21	227	0.6662	13	0.6615	0.9047	No
<= 22 & > 22	233	0.6638	7	0.7369	0.1801	No
<= 23 & > 23	235	0.6646	5	0.7317	0.3885	No
<= 24 & > 24	237	0.6641	3	0.8111	0.0359	Yes
<= 25 & > 25	238	0.6647	2	0.8125	0.2179	No
<= 27 & > 27	239	0.6651	1	0.8667	0	Yes

As can be seen from Table 7, there are three significant differences in the age groups. There is a significant difference when comparing people who are less than or equal to 18 years of age and to those who are older. While there are similar results in the "<=24 & >24" and "<= 27 & > 27" age groups, the number of people in those groups is small, thus the results may change if more people from those groups do the tests.

Comparison of Majors

The users who did the test on the display device can also be categorized into two majors: AE and ME. The ratios of their correct answers are found in Table 8. Normality analyses were executed. For AE, the p-value = 0.8103 and for ME, the p-value = 0.8763. The results of the analysis are accepted.

Table 8

Rates of correct answers by the major of the users using desktop display

	Students	Min	Max	Average	Dispersion
AE	62	0.4083	0.8500	0.6460	0.1127
ME	178	0.3083	0.9667	0.6729	0.1200

The equality of the standard deviations is accepted with p-value = 0.5774. The equality of average rates is also accepted with p-value = 0.1133. Therefore, as can be seen, there is no significant difference between the results of AE and ME.

4.2 Gear VR Results

This subsection presents the results of the users who used the Gear VR. Similarly, to subsection 4.1, the same five analyses can be found, but the data are from the users who used the Gear VR. The subsubsections contain information on the difficulty of the tests, correct answers by gender, primary hand, age, and majors.

4.2.1 Difficulty of the Tests

Firstly, the difficulty of the test types was examined. Similarly, to before the authors grouped the difficulties according to the test types.

Statistical data of the test type difficulties can be seen in Tables 9, 10 and 11. Table 9 shows the rates of correct answers by test type, Table 10 shows the standard deviation of the rates of correct answers and Table 11 compares the rates of correct answers.

Table 9

Rates of correct answers by test type with the Gear VR

	People	Min	Max	Average	Dispersion
MRT	61	0.4833	0.9833	0.8003	0.1248
MCT	61	0	0.8000	0.4071	0.1722
PSVT	61	0.0667	1	0.72295	0.1886

Table 10

Standard deviations of rates of correct answers with the Gear VR, showing what is equal (eq)

	MRT			MCT			PSVT		
	Test stat.	Sign.	Eq.	Test stat.	Sign.	Eq.	Test stat.	Sign.	Eq.
MRT	1	1	Yes	0.5247	0.0136	No	0.4376	0.0016	No
MCT	0.5247	0.0136	No	1	1	Yes	0.8340	0.4842	Yes
PSVT	0.4376	0.0016	No	0.8340	0.4842	Yes	1	1	Yes

Table 11

Comparison of average rates of correct answers with the Gear VR, also showing what is equal (eq)

	MRT			MCT			PSVT		
	Test stat.	Sign.	Eq.	Test stat.	Sign.	Eq.	Test stat.	Sign.	Eq.
MRT	0	1	Yes	14.437	0	No	2.6704	0.0087	No
MCT	14.437	0	No	0	1	Yes	-9.657	0	No
PSVT	2.6704	0.0087	No	-9.657	0	No	0	1	Yes

Similarly, to the desktop display, every test mode is distinguishable. However, with the Gear VR, comparing only the dispersions, in some cases there are no, but in other cases, there are significant differences between them. By investigating the average rates of correct answers, the authors concluded that there are significant differences between all test types. The difficulty is the same as the desktop display results: MCT mode is the most difficult while MRT mode is the easiest.

4.2.2 Comparison of Genders

Out of the 61 users who performed the tests, 44 were male users and 17 were female users. Therefore, the comparison was done regarding the gender of the user. The number of correct answers is found in Table 12. A normality analysis was done with p-value = 0.5377 for males and with p-value = 0.6657 for females.

Table 12

Rates of correct answers by gender using the Gear VR

	Students	Min	Max	Average	Dispersion
Male	44	0.3667	0.9000	0.6790	0.1247
Female	17	0.4417	0.8000	0.6922	0.1092

The equality of the dispersions is accepted, (p-value = 0.5757), and the equality of average rates is also accepted at a high-level of significance (p-value = 0.6875). Therefore, there is no significant difference between the two genders.

However, this nonexistence of the significant difference is a different result than the result with the desktop display: In the previous subsection, the result was that the male users performed significantly better than the female users when using a desktop display. This means that by using the Gear VR, the females performed better than their desktop display counterparts. More information on this different result is available in the next subsection.

4.2.3 Comparison of the Primary Hand of the User

Next, a comparison was made regarding the primary hand of the users. A normality analysis was done, the hypothesis of Gauss distribution is accepted at high levels of significance (p-value = 0.3623 for the right-handed and p-value = 0.9937 for the left-handed users).

Table 13

Rates of correct answers by primary hand with the Gear VR

	Students	Min	Max	Average rate	Dispersion
Right-handed	52	0.3667	0.8583	0.6922	0.1193
Left-handed	9	0.6000	0.9000	0.7611	0.0938

The equality of the standard deviations is accepted (p-value = 0.4826), but the equality of average rates is rejected on the level of significance 0.05 (p-value = 0.02201.

Thus, by using the Gear VR, the left-handed users performed significantly better than their right-handed counterparts. This result is different from the last subsection, as when using a desktop display, there was no significant difference between the performance of left-handed and right-handed users.

This means that the Gear VR not only improved on the performance of the female users but on the performance of left-handed users as well. More information on these different results is available in the next subsection.

4.2.4 Comparison of Age Groups

After the data regarding the primary hand of the user was evaluated, the next data to analyze is the age groups. For information regarding the different age groups, see Tables 14 and 15.

In Table 14, the statistical data of correct answers using the Gear VR is presented and grouped by age groups. The number of people, the group average and the group dispersion can be seen.

In Table 15, the different age groups who took the tests with the Gear VR are compared and examined: The “Less than and equal to” certain age groups were compared to “greater than” certain age groups. The results are the following:

Table 14

Statistical data of correct answers by age groups with the Gear VR

Age	Number of students in the group	Average rate	Dispersion
19	3	0.7306	0.1008
20	4	0.6	0.1763
21	9	0.6296	0.1176
22	10	0.6667	0.1153
23	11	0.672	0.1492
24	8	0.6938	0.1006
25	4	0.725	0.1369
26	3	0.6944	0.0376
27	3	0.75	0.1228
28	2	0.7542	0.0412
30	1	0.8083	0
31	1	0.6583	0
32	1	0.8083	0
34	1	0.7583	0

Table 15

Comparing different age groups who used the Gear VR

Age	Group 1	Avg. rate 1	Group 2	Avg. rate 2	p-value	Significant difference
<= 19 & > 19	3	0.7306	58	0.6802	0.4812	No
<= 20 & > 20	7	0.656	54	0.6861	0.633	No
<= 21 & > 21	16	0.6411	45	0.6974	0.1396	No
<= 22 & > 22	26	0.651	35	0.7062	0.0792	No
<= 23 & > 23	37	0.6572	24	0.7219	0.0266	Yes
<= 24 & > 24	45	0.6637	16	0.6637	0.0163	Yes
<= 25 & > 25	49	0.6687	12	0.6687	0.0155	Yes
<= 26 & > 26	52	0.6702	9	0.6702	0.014	Yes
<= 27 & > 27	55	0.6745	6	0.6745	0.0157	Yes
<= 28 & > 28	57	0.6773	4	0.6773	0.0996	No
<= 30 & > 30	58	0.6796	3	0.6796	0.2915	No
<= 31 & > 31	59	0.6792	2	0.6792	0.0753	No
<= 32 & > 32	60	0.6814	1	0.6814	0	Yes

As can be seen from Table 15 above, the users who are 23-year-old's or are older, tested with the Gear VR have achieved significantly better results than the ones who are younger.

4.2.5 Comparison of Majors

Since the users who tested the application majored in different areas than the ones in Debrecen, the authors set up a new category. When comparing the "majored in" areas, the authors set up two categories: IT students and non-IT students. For information, see Table 16 which presents the rates of correct answers.

Table 16
Rates of correct answers by the major using Gear VR

	Students	Min	Max	Average	Dispersion
IT	21	0.4417	0.8667	0.6845	0.1103
Non-IT	40	0.3667	0.9000	0.6817	0.1259

The hypotheses of Gauss distribution were accepted (p-value = 0.9854 for IT students and p-value = 0.2599 for non-IT students). The equality of the dispersions is accepted (p-value = 0.5338), and so is the equality of the average rates (p-value = 0.9275). Therefore, there is no significant difference concerning the spatial skills measured by our tests between IT students and non-IT students.

4.3 Comparison of Gear VR and Desktop Display Device Results

In this subsection, the authors compare the results of the desktop display and the Gear VR. A comparison is done with the same statistical data as seen in the subsections above. This means the difficulty of the tests, correct answers by gender, by primary hand, and by age. The authors wanted to compare the results by majors, but due to different majors at the universities, it could not be done.

4.3.1 Difficulty of the Tests

The difficulty of the tests was compared in each case. The data can be seen in the following table. D means desktop display, VR means the Gear VR. 1 is the MRT test, 2 is the MCT test, and 3 is the PSVT test. Table 17 presents the rates of correct answers by test type using different display devices.

Table 17
Rates of correct answers by test type with each display device

Device	Students	Min	Max	Average rates	Dispersion
D1	240	0.4167	1	0.8041	0.1334
VR1	61	0.4833	0.9833	0.8003	0.1248
D2	240	0.1333	0.9667	0.4389	0.154
VR2	61	0	0.8	0.4071	0.1723
D3	240	0.1333	0.9667	0.6168	0.1932
VR3	61	0.0667	1	0.723	0.1886

The equality of the standard deviations is accepted in cases D1-VR1 (p-value = 0.5476), D2-VR2 (p-value = 0.2454), D3-VR3 (p-value = 0.8456). The equality of average rates is accepted in the first two cases only: D1-VR1 (p-value = 0.8336) and D2-VR2 (p-value = 0.1924). In case of D3-VR3, the hypothesis of equality is rejected (p-value = 0.0001766), thus the Gear VR users performed significantly better performing the PSVT tests when compared with the desktop display devices.

4.3.2 Ratio of Correct Answers

Statistical data of the ratio of correct answers with each display device can be seen in Table 18. This ratio is illustrated in Figure 2 with cumulative distribution functions.

Table 18
Rates of correct answers with each display device

	Students	Min	Max	Average rate	Standard deviation
Desktop display	240	0.3083	0.9667	0.6660	0.1185
Gear VR	61	0.3667	0.9000	0.6827	0.1199

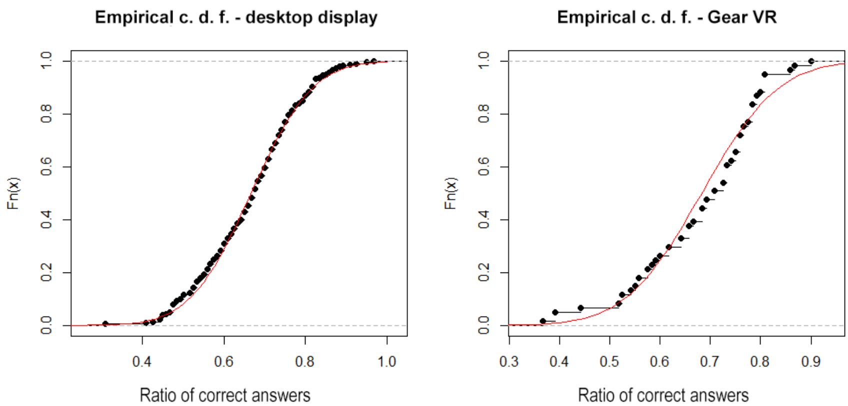

Figure 2
Ratio of correct answers for desktop displays (left) and the Gear VR (right)

Normality analyses were done for both devices. The p-value is 0.6335 for desktop displays and the p-value is 0.2548 for the Gear VR, hence the hypotheses of Gauss distributions were accepted in both cases.

The hypotheses of the equality of the dispersions and the expectations are accepted (p-value is 0.8786, and p-value = 0.3332, respectively) thus there is no significant difference of the correct answers between the two devices.

4.3.3 Comparison of Genders

Table 19
Rates of correct answers by gender using the different display device

	Students	Min	Max	Average	Dispersion
Desktop display, Male	211	0.3083	0.9667	0.6769	0.1172
Gear VR, Male	44	0.3667	0.9000	0.6790	0.1247
Desktop display, Female	29	0.4417	0.7833	0.5865	0.0965
Gear VR, Female	17	0.4417	0.8000	0.6922	0.1092

When comparing the male desktop display testers to the male Gear VR testers and with the data from Table 19 (illustrated in Figure 3), the equality of the standard deviations (p-value = 0.5609) and the averages (p-value = 0.9193) are both accepted. Moreover, the distribution of the two groups is tested, the equality of the distributions is accepted (p-value is 0.7931). Therefore, there is no significant difference between the two male groups. However, the result is different between the two female groups. When looking at the standard deviations, the equality is accepted with p-value = 0.5513, but when looking at the average rates, the equality is rejected with (p-value = 0.0024). This means that there is a significant improvement in the Gear VR female group. When the equality of the two distributions is tested, it is refused with p-value = 0.02125.

4.3.4 Comparison of the Primary Hand of the Users

Next step was to analyze based on the primary hands of the users.

Table 20
Rates of correct answers by primary hand with each display device

	Students	Min	Max	Average rate	Standard deviation
Desktop display, Right-handed	213	0.3083	0.9667	0.6691	0.1177
Gear VR, Right-handed	52	0.3667	0.8583	0.6691	0.1193
Desktop display, Left-handed	27	0.4417	0.8833	0.6414	0.1242
Gear VR, Left-handed	9	0.6000	0.9000	0.7611	0.0938

A comparison was done between the two right-handed groups, see Table 20 and Figure 4 for illustration. The equality of the standard deviations and also of the average rates are accepted on very high levels (p-value = 0.8633 and p-value = 0.9991, respectively) and the equality of the distributions is also accepted (p-value = 0.7086). Therefore, there is no significant difference between the two right-handed groups. The result is different between the two left-handed groups: The equality of the standard deviations is accepted (p-value = 0.4164), but the equality of average rates is rejected (p-value = 0.006949). This means that there is a significant improvement with the use of Gear VR in the case of the left-handed group.

4.3.5 Comparison of Age Groups

When doing a comparison between the two devices, a significant difference was found in age comparison. To achieve this result, four age groups were made: Users who tested with a desktop display device and are less than or equal to 18 years of age (DU18), or over 18 (DO18). The remaining two groups are users who tested with the Gear VR device and are less than or equal to 23 years of age (VRU23) or over 23 (VRO23).

The age groups were divided at these ages, as there were differences that could be seen. These data can be found in Table 21.

Table 21
Statistical data of correct answers by age groups with each display device

	Students	Min	Max	Average rates	Dispersion
DU18	34	0.3083	0.8583	0.6245	0.1224
VRU23	37	0.3667	0.9	0.6572	0.1297
DO18	206	0.4083	0.9667	0.6728	0.1167
VRO23	24	0.5417	0.8667	0.7219	0.0921

The equality of standard deviations is accepted (p-value = 0.739) in category DU18, VRU23, and is also accepted in category DO18 and VRO23 (p-value = 0.1794). The equality of expected rate values is accepted (p-value = 0.2784) in category DU18, VRU23. However, there is a significant difference between DO18 and VRO23 categories (p-value 0.02259). Therefore, the users who are over 23 and tested with the Gear VR are significantly better than the users who tested with the display device and are over 18.

5 Discussion

Since spatial ability is an important skill, tests were conducted. Data are collected by using the application and the collected data are analyzed. This produced the statistical results, as can be seen in multiple tables and figures in the previous section. Therefore, from the results, the authors accept hypotheses H3, H5, H7, H10, and H11. The answers for hypotheses H1 and H6 are mixed. The first half of them is rejected, the second half is accepted. The remaining hypotheses H2, H4, H8, H9 are fully rejected.

5.1 Accepted Hypotheses

Since left-handed users use the right side of their brain more often, the authors suspected that left-handed people perform better on the tests (alternative hypotheses of H3 and H8). However, according to Tables 5, 13 and 20, H3 is accepted, forming T3: There is no significant difference between the performances of left-handed and right-handed people who used a desktop display.

Concerning H5 and H10, the statistics can be seen in Tables 8 and 16. Both H5 and H10 can be accepted. H5 forms T5: There is no significant difference in the performance of architectural engineering and mechanical engineering students when using a desktop display. Similarly, to H5, H10 forms T10: There is no significant difference in performance between IT and non-IT students when using the Gear VR.

Since the tests were conducted at two different universities, the majors of the students differ. However, the authors believe after forming T5 and T10 that the majors of the users do not influence their performance.

Concerning H7, by using the Gear VR, there is no significant difference between the performances of males and females. This is a different result in comparison to the result of the desktop display. This forms the following T7: Female users perform better numerically on the spatial ability tests than males by 1.94% on average with the Gear VR.

Taking RQ11 and H11 into account when formulating thesis T11, it can be seen from Table 18 that when using the Gear VR, the users can produce better results on the tests. Thus, H11 is accepted. This fact yields thesis T11: There is no significant difference in the ratio of correct answers when comparing desktop displays with the Gear VR, but with the latter, the users produced numerically a better average of correct results by 2.5%.

5.2 Mixed Cases

As mentioned before, hypotheses H1 and H6 present mixed cases. What can easily be seen from Tables 1, 2, 3, 9, 10, 11 and 17, that the users found the MCT test mode the hardest and the MRT test mode the easiest. Therefore, the first half of both H1 and H6 is rejected, and the second half is accepted. H1 forms thesis T1: The users who used a desktop display / Gear VR found the MCT test mode the hardest, and the MRT mode the easiest.

Comparing the devices, there is a new piece of information available in Table 17: Users of the Gear VR performed significantly better on the PSVT tests than their counterparts who used a desktop display. Therefore, T6 is the following: While there are no significant changes in the ratio of correct answers in the MRT, MCT test mode when comparing the desktop display to the Gear VR, the users who tested with the latter performed significantly better (17.217%) in the PSVT test mode.

5.3 Rejected Hypotheses

Investigating H2, Tables 4, 12 and 19 are taken into account. Table 4 shows the desktop display results, Table 12 shows the Gear VR results and Table 19 compares both of them. According to the mentioned tables, T2 is formed: When using a desktop display, there is a significant difference between males and females, meaning males perform better on the tests than females by 15.41% on average. This fact is similar to older studies not featuring VR, such as [19] where it is proven that males have better spatial skills than females. When using the Gear VR, however, this significant difference disappears, meaning that the females perform better on the tests than males by 1.94% on average. This means that the Gear improves especially the women's achievements, which is an interesting result.

H4 is rejected, as can be seen from Table 7. This formulates T4: The users who used a desktop display and are over 18 years of age performed better by 7.73% on average than their younger counterparts.

H8 is also rejected. With H8, T8 can be formed: There is a significant difference in the performance of the left-handed and right-handed people who used the Gear VR. The difference is quite large, it is about 7%. This means that the performance of the left-handed people was increased significantly by the Gear VR, as Section 4.3.4 shows, the increment is about 13%. This result is quite different from older studies not featuring VR, such as [20] where they concluded that right-handed people outperformed left-handed people. It seems like using a desktop display makes their performance equal and when using the Gear VR, left-handed people outperform right-handed ones.

Similarly, to H4, H9 is rejected as well. Data for this can be seen in Table 15. T9 is formed: The users who used the Gear VR and are over 23 years of age performed significantly better than their younger counterparts. (The difference is 9.4% numerically.) Comparing displays, Gear VR users who are over 23 years of age performed significantly better than the users who are over 18 years of age and used a desktop display (the difference is 7.29% on average).

Conclusions

A well-developed spatial ability is an important cognitive skill in the modern age. In the last century, only paper-based methods were available, but with the coming of the digital world, the number of methods is increasing. With virtual environments in virtual worlds, new methods can be created, or existing methods can be improved upon.

The CogInfoCom supported education has several advantages to improve the effectiveness of learning. For example, through the benefits and opportunities of Virtual Labs [21], gamification or team-based collaborative education [22, 23, 24], Human-Computer Interfaces [25, 26, 27], Virtual Reality-based learning spaces [28] and other educational environments [29, 30].

The authors of this paper created such a VR application that presents three old methods – MRT, MCT and PSVT – in a new context. This application allows to get data in real-time from the spatial ability tests and is also available on two platforms: PC and Android.

This application was tested by 61 students on the Android platform with the Gear VR and by 240 students on the PC platform with an LG desktop display. Data were gathered from the users and were analyzed. The data consisted of the age of the user, gender of the user, primary hand of the user, the number of years spent at the university and what the student majored in.

Eleven research questions and hypotheses were made in the beginning. Five theses were formed from five accepted hypotheses, four were formed from rejected hypotheses and two from mixed hypotheses.

With these eleven theses, it can be concluded that the Gear VR offers a significant improvement to the spatial performance of female users, left-handed users, and older users. With the use of the Gear VR, the PSVT test mode also becomes significantly easier to the users.

According to the results, the use of a VR headset positively influences the spatial skills of the users. This is good, as most education for engineers at universities contain subjects such as technical representation or descriptive geometry and a well-developed spatial ability is necessary for successful studies.

In conclusion, it can be safely stated that the use of virtual environments and virtual reality can help with developing and improving the spatial skills of students. Also, these results strengthen the fact that virtual reality has a future in education.

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Evaluation of Eye-Movement Metrics in a Software Debugging Task using GP3 Eye Tracker

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Abstract: Teaching different programming subjects is an increasing challenge nowadays as because of growing user demands, the latest paradigms and technologies must be taught. Students in higher education now are of the age who were born into the digital world; however, the success of fulfilling programming courses is lagging behind. Human-computer interface-based research has emerged in numerous fields of science recently, which could lead to the revolutionising of education. These interfaces could also help professors as a support system in transferring knowledge in a more efficient way besides supporting students acquiring adequate home learning methods. In this study, the applicability of eye movement tracking systems in respect of a programming task is examined, in which during the exploration and correction of the errors of an incorrectly functioning algorithm, the eye movement parameters are observed, recorded and evaluated. The test subjects participating in the research were divided into two groups according to some of their characteristic parameters, where the first group during debugging rather applied minor modifications and the more common technique of compile and run, which otherwise is also the most characteristic feature of students studying programming, while the members of the other group increased emphasis on analysing. In the statistic evaluation of the research, the parameters characteristic of the eye movement tracking of the two groups, as well as the efficiency of these groups were analysed. Based on the results, regarding the efficiency and the number of fixations, a significant difference could be shown between the two groups ($U=22.5$, $Z=-2.236$, $p=0.025$ (2-tailed), $r=0.48$) and ($t(20)=2.507$, $p=0.021$ (2-tailed), $d=1.106$), while concerning the duration of fixation and the saccade length, the difference shown was infinitesimal ($t(20)=0.544$, $p=0.592$ (2-tailed), $d=0.26$) and ($t(19.992)=1.965$, $p=0.063$ (2-tailed), $d=0.79$).

Keywords: eye-tracking; programming; debugging; education

1 Introduction

Understanding complex cognitive processes can provide great help in education. Human-computer interfaces are such technologies that could emerge as a support system in the fields of teaching and learning. Teachers could achieve more efficient knowledge transfer, while students could gain adequate learning methods by applying them. Teaching programming has become a complex task nowadays, as the software solutions to be produced and maintained are growing in size and they are increasingly difficult to handle despite the available newer and newer paradigms and technologies compared to the past; moreover, students find it hard to acquire applying these devices because of their complexity. Designing, preparing, testing and maintaining source code bases are becoming a more complex cognitive process; therefore, research aiming to increase the efficiency of development phases and reduce their costs are being in focus. One of the possibilities is the analysis and examination of eye movement tracking, whereas the observation of gaze can provide an opportunity to explore basic and more complex cognitive mechanisms [1].

The [1] research deals with the metrics of the route of the gaze in respect of software development; it encourages the standardisation of these features and makes various suggestions for their applications. Some studies examine the steps of the designing phase of the software development life cycle in which UML class diagrams that create the frame of object-oriented programs and are strongly present in higher education are designed and applied [2-4], moreover, further studies analyses the arrangement [5, 6] and intelligibility of these diagrams [7]. The understand ability of Business Process Models (BPMN diagrams) is examined in the study [8], while that of the Entity-Relationship Diagrams (ERD) is examined in [9]. The reading of traditional, native language texts is analysed and compared to the readability of different source codes in other articles. The results among others showed that the methods of the reading and overview of the two text types are different, as in case of program codes, more fixation time could be shown. Another result proves that beginner programmers spend more time reading comments than experienced programmers [10-13]. The study [14] was the first research in which large source code was tested in relation to eye movement with open source code software support.

In this research, the forms and efficiency of debugging sections of software development are examined with eye movement tracking with the involvement of test subjects. The route of the gaze of the test subjects was observed continuously during the process, and coherences were determined by the evaluation of the recorded metrics. The eye movement tracking hardware and software units, as well as the test algorithm applied in the research are described in Chapter 2.The circumstances of the inquiry are introduced in Chapter 3, including the data of the test subjects and the steps of the completion of the research. The evaluation of the results is detailed in Chapter 4, while in Chapter 5, the conclusions made from the results are summarised.

2 The Hardware Unit, the Software Package and the Algorithm Applied in the Research

The GazePoint 3 (GP3) eye-tracker hardware unit and the OGAMA software package were used in the research to observe eye-movement tracking and to record the metrics. The applied algorithm of the examination, uniting two disordered blocks (unification), was well known for the test subjects from their previous studies.

2.1 The GazepointGP3 Eye-Tracker Hardware Unit

During the study, to observe and record the route of the gaze of the test subjects, a general-purpose research-grade device, the GazepointGP3 eye-tracker (Fig. 1) was applied, which had successfully been applied in some previous research. [15-21] It is an ultra-portable device (320 x 45 x 40 mm, 145 g) that can move 25 cm horizontally, 11 cm vertically and 15 cm in-depth; it can be fitted on the monitor and uses infra camera observation and image procession to detect and follow eye movement with 60 Hz sample rate. It is easy to handle with 0.5-1 degree of visual angle and 5-or 9 point-calibration options. The device can be used at least in case of 24” or smaller displays, with at least Intel Core i7 or faster processors, with 8 GB RAM and with Windows 7, 8.1 or 10 operating system. At present, the Mac and Linux operating systems are not supported. In addition, it also has an API/SDK package that supports software development possibilities related to the device.

Fig. 1.
The GazepointGP3 Eye Tracker

2.2 The OGAMA Software Package

The OGAMA (OpenGazeAndMouseAnalyzer) is an open-source code application that was implemented by Adrian Voßkühler at the Freie Universität Berlin to track eye and mouse movements and to record and analyse the received parameters implemented in C# high-level programming language.NET frame system. For the adequate use of the application, an eye movement tracking hardware unit, a Windows operating system by Microsoft, the .NET frame system and the SQL

Express database server are needed. The main features of the application include slideshow design, database-driven pre-processing, attention map creation, filtering, and recording of gaze and mouse movement data and the areas of interest definition. Furthermore, data stored in the database can be exported for different statistic software in proper formats, which eases efficient statistic evaluation. The application supports several gaze routes observing and recording hardware units, including the GazepointGP3 hardware unit as well. In addition, the program can be modified or further developed according to our needs. The software package has been successfully applied in several researches. [21-23]

2.3 The Applied Test Algorithm

The test subject had to correct errors hidden in unification known from their previous studies, wherein the correct original algorithm an N and an M element sets are available depicted in *A* and *B* vectors. The unification of the two sets is represented in the *C* vector, to which those elements belong to that are present in at least one of them. During the procession, the content of the *A* vector is copied into *C* at first, which has an *N* element, and then each element of the *B* vector has to be found an *A* correspondent. If such an element cannot be found, so $i>M$, the j element of the *B* vector goes to the *C* vector. The description of the original union of two unsorted array pseudo can be seen in Fig. 2.

ALGORITHM ORIGINAL UNION OF TWO UNSORTED ARRAYS (*A, B, C, N, M*)

```
for i ← 1 to N do
    C[i] ← A[i]
end for
count ← N
for j ← 1 to M do
    i ← 1
    while i<=N and A[i] ≠B[j]do
        i ← i + 1
    end while
    if i>=N then
        C[count] ← B[j]
        count ← count + 1
    end if
end for
```

Fig. 2.
Original Union of Two Unsorted Array Algorithm

In the correct union algorithm above, three errors were hidden, which had to be found and corrected by the test subjects. The artificially generated errors were the following:

1. The conditional statement part of the *for* cycle was modified to *N-1*, so the last element of the *A* vector can never be transferred into the *C* vector.

2. The index reference of the *C* vector was changed from *count* to *i*, and as a result, the last element of the *B* vector that cannot be found in the *A* vector will only be transferred to the *N* (*A.length+1*) position of the *C* vector.

3. Within the *if* conditional branch, the incremental expression (*count* = *count* + *1*) was changed into a decremental expression (*count* = *count* - 1) and a result of this, the first element of the *B* vector that cannot be found in the *A* vector will only be transferred to the *N* (*A.length+1*) position of the *C* vector.

The description of the modified union of two unsorted array pseudo can be seen in Fig. 3, where the modifications are indicated in red.

ALGORITHM MODIFIED UNION OF TWO UNSORTED ARRAYS (*A, B, C, N, M*)

```
for i ← 1 to N-1do
    C[i] ← A[i]
end for
count ← N
for j ← 1 to M do
    i ← N
    while i<= N and A[i] ≠ B[j]do
        i ← i + 1
    end while
    if i>=N then
        C[i] ← B[j]
        count ← count - 1
    end if
end for
```

Fig. 3.
Modified Union of Two Unsorted Array Algorithm

The modified algorithm demonstrated above was implemented in C# programming language using the Visual Studio Community development environment, which was best known for the test subjects.

3 The Circumstances of the Examination

The research was carried out with the application of the Gazepoint GP3 eye-tracker hardware unit, the OGAMA software package and the modified unification algorithm all described in detail in the previous chapter. The test subjects were given a maximum of three minutes to explore and correct the hidden errors, and they were allowed to compile and run the application several times. An LG 22M45 type with 1920x1080 resolution, 22” diameter monitor was applied to display the modified algorithm.

3.1 The Test Subjects

Twenty-two university students, ten females and twelve males aged between 18 and 22, who claimed themselves to be wholly healthy and were not on any medication, were involved voluntarily in the research. The only condition of the participation was the successful compliance of the Introduction to Programming course, as this subject contains the necessary algorithm knowledge and algorithmic thinking to complete the test.

3.2 The Steps of the Test

Before connecting the GP3 eye-tracker hardware unit, the Gazepoint software package was installed, which contains the camera driver among others. After successful installation, the device was connected through a USB port. After connecting the device, it was positioned under the monitor approximately 65 cm length distance from the eyes. It was avoided in every case that the face of the test subjects is exposed to sunlight. After the adequate placement of the device, the modified algorithm was opened in the Visual Studio Community development environment. It was positioned to fill the screen as much as it could. After opening the modified algorithm, the Gazepoint Control application was started, which supported the configuration and the start of the gaze-date server, ensuring real-time information obtaining. The next step was to start the OGAMA software, where before beginning the test, the Recording module was selected in the OGAMA application and the connection to the hardware unit was completed. After the preparations, the test subjects were seated one after another, one by one, and the testing process was explained to them. Right before starting the test, the data of the test subjects were saved. After successful data registration, the calibration of the device had to be done, during which the test subjects had to track a circle with eye movement from the top left corner of the monitor without moving their heads.

For the best results, calibration was done even more times in the case of each person. After successful calibration, the test subjects could start the error search and correction. During the research, the different eye movement parameters were observed and recorded, and after finishing the test, the data were saved into a database for further statistic evaluation. The process and the environment of the test can be seen in Fig. 4.

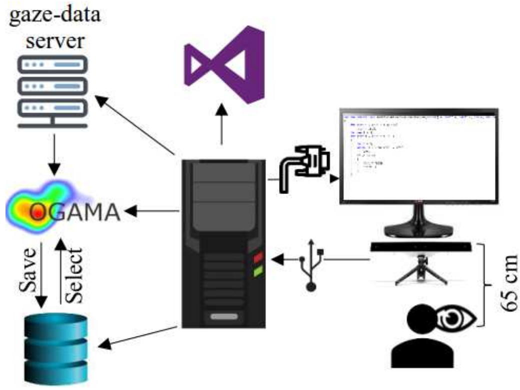

Fig. 4.
A schematic diagram of the equipment setup

3.3 Definied Metrics

The successfulness was defined on a scale between 0 and 3, where the points of efficiency were equal to the numbers of the found bugs. The test subjects had a maximum of 3 minutes to detect and correct the errors because the time factor would be used as a measure of efficiency during the examination.

4 Results

During the evaluation of the recorded results, two groups were set based on the way of problem-solving. Test subjects who after many minor modifications tried to explore and correct the errors with more compile and run were put into the first group (Try&R), while those who rather analysed the algorithm and applied compile and run relatively fewer times, maximum at five times, were ranked into the second group (Think&R).

4.1 Testing the Efficiency and the Rapidity of the Groups

It became clear after the test that more, actually 15 test subjects, applied smaller corrections and multiple runs, so they rather "tried" to do their task. Therefore, they were put in the Try&R group, while 7 test subjects showed more consideration and analysing, so they rather "thought" and were placed therefore in the Think&R group.

Based on the Try&R results, it can be claimed that two people in the group were able to absolve the task, despite many smaller modifications and attempts; however, two other test subjects were not able to correct any errors. Regarding time, it took 84 seconds to find and correct all errors for the quickest test subject, while thirteen test subjects reached the maximum time limit. The average of efficiency regarding the whole group was 1.67±0.90. More test subjects ran out of the given three minutes, presumably because of their precipitance and little consideration. The average time was 169.067±29,33 seconds regarding the whole group. All in all, two of the fifteen test subjects were able to find and correct all errors within the target time, and it shows 13% successfulness. Fig. 5 shows the distribution of efficiency of the Try&R group, which greatly shows that two errors were found and corrected within the maximum time limit by most test subjects.

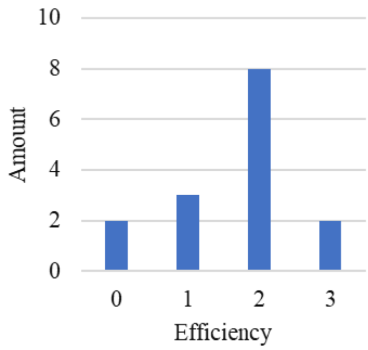

Fig. 5.
The distribution of efficiency of the Try&Rgroup

According to the results of the Think&R group, it can be stated that five people were able to solve the task correctly; however, there were not any test subjects who could not find and correct any errors, the worst result was finding and correcting only one error. Regarding the time, the fastest test subject needed a little bit more than one minute to find and correct all mistakes, while three people reached the maximum time limit. The average efficiency of the whole group was 2.57±0.79. Two test subjects ran out of the three minutes, but proportionally they were much less than in the previous group. The average time of solving the task was 136.86±44.13 seconds regarding the whole group. Overall, 5 out of the 7 people were able to find and correct all errors within the target time, and that shows 71% successfulness, which means significant positive difference comparing to the results of the Try&R group. Presumably more careful consideration and less precipitance lie behind the better results. Fig. 6 shows the distribution of efficiency of the Think&R group, which reflects that most test subjects, could find and correct all errors within the given time limit.

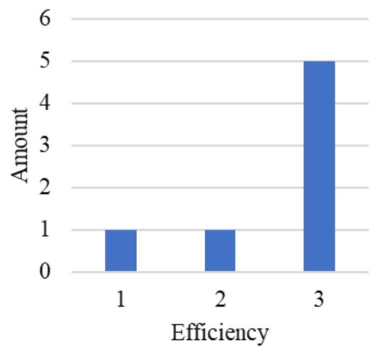

Fig. 6.
The distribution of efficiency of the Think&R group

A summary of the evaluation above can be seen in Table I, showing the efficiency of each test subject and the time necessary to fulfil the task. At the bottom of the table, the minimum and maximum value of the results reached in the groups, their average, and standard deviation are given.

TABLE I.
A SUMMARY TABLE ABOUT THE EFFICIENCY OF THE GROUPS

	TRY&R		**THINK&R**	
Test subjects	**Efficiency[1] (points)**	**Time[2] (s)**	**Efficiency[1] (points)**	**Time[2] (s)**
1.	1	180	3	134
2.	1	180	3	172
3.	2	180	2	180
4.	0	180	1	180
5.	2	180	3	124
6.	1	180	3	62
7.	3	112	3	106
8.	2	180		
9.	2	180		
10.	2	180		
11.	0	180		
12.	2	180		
13.	3	84		
14.	2	180		
15.	2	180		
Min	**0**	**84**	**1**	**62**
Max	**3**	**180**	**3**	**180**
Average	**1.67±0.90**	**169.07±29.33**	**2.57±0.79**	**136.86±44.13**

[1]The maximum points were 3.
[2]The maximum time was 180 s.

The data of average efficiency in case of the Try&R and the Think&R groups were analysed on an ordinal scale, therefore, it was determined with the Mann-Whitney test that between the average of the efficiency of the two groups, a statistically significant difference could be found (U=22.5, Z=-2.236, p=0.025 (2-tailed), r=0.48) taking into account the maximum 180 seconds time limit.

4.2 The Evaluation of the Parameters of the Eye Movement

During the examination of the parameters of the eye movement, the attention maps generated by the OGAMA software were analysed at first, which were determined while recording the route of the gaze. Besides the attention map, the number of fixations, the average fixation duration as well as the average saccade lengths in pixels was examined, too.

4.2.1 The Evaluation of the Recorded Attention Maps

The applied colours in the attention map mean the following:

- transparent field: observed, focused area for only a very short time or not at all;
- green: observed, focused area for a short time;
- yellow: observed, focused area for a medium length of time;
- red: observed, focused area for a longer time.

Fig. 7 shows a map characteristic of the Try&R group, while Fig. 8 shows that of the Think&R group. Regarding the members of the two groups, the received results are similar. In case of the Try&R group, it can be seen that the route of gaze is more diversified; the less important part of the algorithm was paid more attention than necessary, too. It reflects the hesitancy well, as presumably, the gaze returned to a previously relatively shortly observed and examined field, even if that certain code part did not contain any errors and the test subjects could have been ascertained about that earlier. On the whole, it can be stated that a characteristic feature of the members of the Try&R group is diverse attention, which is also proved by the generated attention maps.

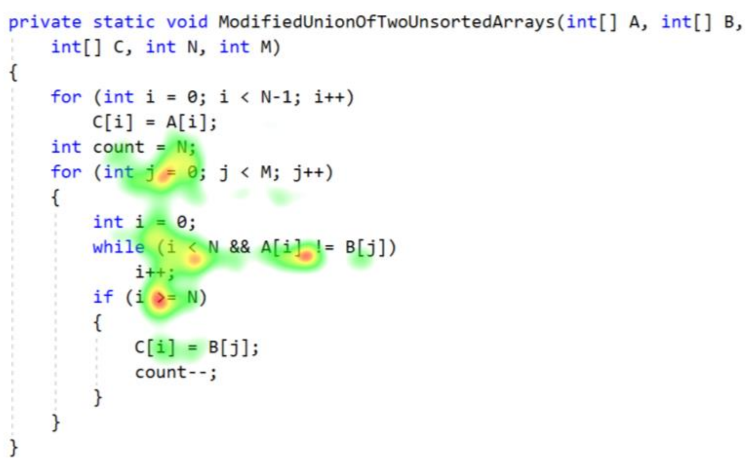

Fig. 7.
The attention map of the 12th test subject in the Try&R group (Efficiency = 2, Time = 180 s)

In case of the Think&R group, it could be observed that the less important areas were paid little attention to according to the gaze route, while the incorrect parts of the algorithm were more focused on than in case of the members of the Try&R group. It can assume more careful consideration and concentrated attention, which is proven by the attention maps.

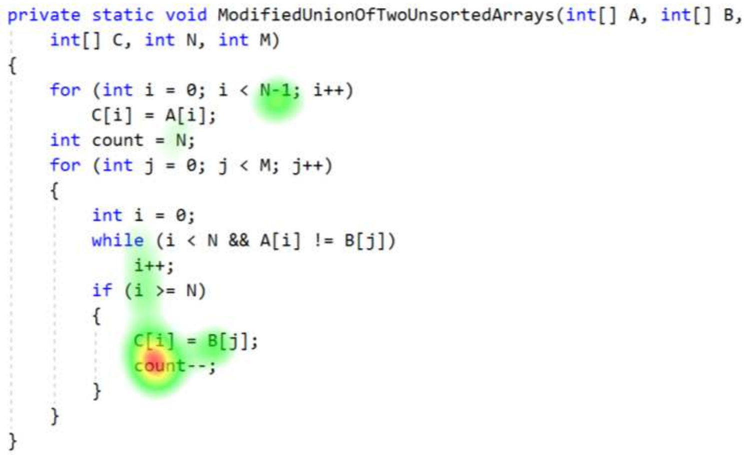

Fig. 8.
The attention map of the 5th test subject in the Think&Rgroup (Efficiency = 3, Time = 124s).

4.2.1 The Evaluation of the Index Numbers of the Eye Movement

The first evaluation of the eye movement index number was defined by the number of fixations. In case of the Try&R and the Think&R groups, during the examination of normality of the fixation data, the Shapiro-Wilk (D(15)=0.904, p=0.110 and D(7)=0.901, p=0.339) test results are not significant, and the standard deviations are not consentaneous either (F=0.021, p=0.887), furthermore, at the evaluation, the average of interval variables were compared in two groups independent of each other, therefore, two-sample t-test was applied, which shows that the average of the number of fixations is significantly different in the two groups ($t(20)=2.507$, $p=0.021$ (2-tailed), d=1.106). In case of the Try&R group, the average fixation quantity is 210.67±50.06, while in the Think&R group, it is 149.57±59.98. The distribution of the number of fixations is shown in Fig. 9.

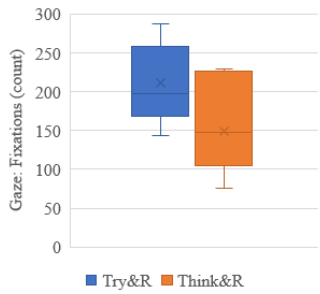

Fig. 9.
The distribution of Gaze: Fixations (count) of the groups

The second evaluation of the eye movement index number was carried out regarding the average fixation duration. In case of the Try&R and the Think&R groups, during the examination of normality of the average fixation duration data, the Shapiro-Wilk test results ($D(15)=0.960$, $p=0.691$ and $D(7)=0.944$, $p=0.672$) are not significant, and the standard deviations are not consentaneous either (F=0.654, p=0.428), therefore, as in case of the evaluation of the quantity of fixation, the two-sample t-test was applied, which shows that the average of the fixation period of time is not significantly different in the two groups ($t(20)=-0.544$, $p=0.592$ (2-tailed), $d=0.26$). In case of the Try&R group, the average fixation period is 364.01±85.62, while in the Think&R group, it is 383.96±65.71. The distribution of the average fixation duration is shown in Fig. 10.

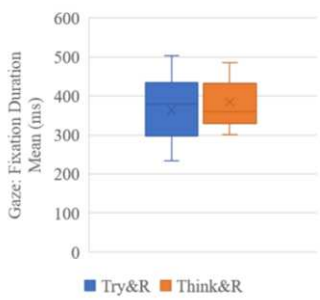

Fig. 10.
The distribution of Gaze: Fixation Duration Mean (ms) of the groups

The third and last evaluation of the eye movement index number was executed regarding the average saccade length. In case of the Try&R and the Think&R groups, during the examination of normality of the average saccade length, the Shapiro-Wilk test results ($D(15)=0.932$, $p=0.294$ and $D(7)=0.838$, $p=0.096$) are not significant, but the standard deviations are consentaneous either (F=7.333, p=0.014), the two-sample t-test (Welch) was applied, which shows that the average of the saccade length is not significantly different in the two groups (*t*(19.992)=1.965, *p*=0.063 (2-tailed), *d*=0.79). In case of the Try&R group, the average saccade length is 125.24±29.93 pixels, while in the Think&R group, it is 106.96±13.68 pixels. The distribution of the average saccade length is shown in Fig. 11.

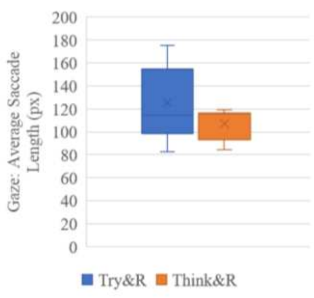

Fig. 11.
The distribution of Gaze: Fixations (count) of the groups

The summary of the evaluation of the data above can be seen in Table II, in which the quantity of fixation, the duration of average fixation and the average saccade length in pixels of each test subjects can be seen. At the bottom of the table, the minimal and the maximal values of the received results of the groups as well as their average value and standard deviations are shown.

TABLE II.
SUMMARY TABLE OF THE PARAMETERS OF THE EYE MOVEMENTSOF THE TWO GROUPS

	TRY&R			THINK&R		
Test subjects	**Gaze: Fixations (count)**	**Gaze: Fixation Duration Mean (ms)**	**Gaze: Average Saccade Length (px)**	**Gaze: Fixations (count)**	**Gaze: Fixation Duration Mean (ms)**	**Gaze: Average Saccade Length (px)**
1.	144	244,48	107,49	227	329,95	92,93
2.	260	317,02	82,33	230	351,56	84,31
3.	258	352,68	95,39	148	432,01	116,40
4.	283	233,70	154,68	105	428,90	115,49
5.	189	297,55	127,47	110	360,04	116,46
6.	151	495,38	175,58	75	300,73	119,27
7.	201	311,55	94,59	152	484,54	103,88
8.	168	386,69	100,95			
9.	197	401,54	114,29			
10.	257	388,26	166,46			
11.	176	451,82	159,43			
12.	288	433,58	137,69			
13.	184	263,58	114,67			
14.	155	379,58	98,24			
15.	249	502,58	149,27			
Min	**144**	**233.70**	**82.33**	**75**	**300.73**	**84.31**
Max	**288**	**502.58**	**175.58**	**230**	**484.54**	**119.27**
Average	**210.66±50.06**	**364.01±85.62**	**125.24±29.93**	**149.57±59.98**	**383.96±65.71**	**106.96±13.68**

5 Discussion

Having examined and evaluated the results, it can be stated that in case of the test subjects of the Try&R group, the several minor modifications and the frequent compile and run shows less efficiency and larger time need to explore and correct the hidden errors in the source code than in the case of the test subjects of the Think&R group. The presumable reason for this phenomenon is uncertainty, diverse attention and the lack of consideration.

The significant difference of the evaluated eye movement parameters experienced in the results of the two groups is also confirmed by the attention maps recorded by the OGAMA software. Based on the map, in case of the Try&R group, the gaze of the test subjects is much more diverse; moreover, the test subjects of this group paid too much attention to the less important parts of the algorithm, which also proves the statement claimed above.

According to the eye movement parameters, it can be stated that a significant difference between the test subjects of the two groups could only be shown in the quantity of fixation. The test subjects in the Try&R group performed more fixations in the source code compared to the members of the Think&R group, that is they needed to gain information from more points of the screen, however, regarding the duration of fixation and the average saccade length, there was no significant difference ivincible, which may refer to the fact that despite the members of the Try&R group examined more points in the source code, they did not study them thoroughly, furthermore, during the visual search many small scanning characterised them, while in the Think&R group these results may mean that longer or shorter fixation duration or visual search was not necessary besides smaller quantity of fixation, so the better results received in the Think&R group is the consequence of the fact that the test subjects needed significantly less fixation to find and correct the errors. As in the duration of the information process, a significant difference cannot be shown, and all test subjects had successfully absolved the Introduction to Programming course, the difference cannot be explained with the knowledge difference of the test subjects. The knowledge gap presumably would have shown larger information processing duration and average saccade length besides the larger quantity of fixation because of indecision.

The findings of the examination suggest that paying attention and consideration to the problems could be a better way of doing the task, leading to efficient debugging. These results can useful for teachers in software development when discussing the best and efficient ways of debugging. In addition, this kind of researches can be of interest not only to science and education, but also to industry. Using the typical patterns and metrics the comprehensibility of a source code can be effectively analysed and the cost of its future maintenance can be estimated with more accurately. Moreover, bug fixes and testing may be accelerated, so the complete development time could be shortened since developers and testers who can understand the whole source code may be discovered. In the future, different software development companies may invest in human-machine interfaces that can provide them more efficient development.

Conclusions

The research on eye movement tracking is increasingly present in such examinations of cognitive processes as programming. This research was carried out by observing the route of the gaze of test subjects during the exploration and correction of an incorrect algorithm and the recorded eye movement parameters were analysed. After the experiment, two groups were formed by applying parameters characteristic of the test subjects, where the first group (Try&R) rather applied the technique of smaller modifications and more frequent compiling and run during debugging, while the members of the second group (Think&R) put more emphasis on analysing and applied less compiling and run of the application. Besides analysing the efficiency, the heat maps generated by the software applied for eye movement tracking were analysed as well, in which the route of the gaze of each test subjects could be tracked well. During the statistic evaluation, the parameters characteristic of the eye movement tracking of the two groups (quantity of fixation, average fixation duration, and average saccade length) and the efficiency of the groups were analysed. As aresult of the research, it can be stated that in case of less precipitance, thorough consideration and attention, less information procession quantity is sufficient to efficient debugging, which can also lead to more efficient software development.

The evaluation of the eye movement parameters could serve as a support for measuring different abilities: from cognitive skills, learning strategies to complex task execution in the field of education. The modern ICT possibilities help achieve these findings using the advantages of VR and AR [24]-[28], mathability [29]-[34], gamification, project-based learning or cooperative methodologies [35]-[41] together with the possibilities of Cognitive Info-communications and similar emerging technologies [42]-[48].

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Quantitative Analysis of Relationship Between Visual Attention and Eye-Hand Coordination

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Abstract: In perception and activity tasks, continuous visual tracking of the performed activity requires continuous eye motion. Besides writing and reading, the cooperative work of eyes and hands is a key factor when drawing and at certain motions (e.g. ball catching or throwing); during the exact execution of motions, eye-hand coordination has the utmost importance. The development of eye-hand coordination plays a key role in education too, regarding several subjects, i.e. writing, drawing, technique and lifestyle, and of course, at complex motion sequences. Modern info-communication tools play an even more significant role in supporting education, where human-computer interfaces similar to the systems introduced in this paper are very significant. In this paper, by analysing certain features describing computer mouse cursor motion, examined during the execution of the Trail Making Task, what correlation is there between visual attention and eye-hand coordination. Based on the statistical correlation analysis results of data, it was determined, that the fixation parameters of eye and hand motion are in negative correlation with visual attention, while the distance between the look and the mouse cursor's motion are not correlated to each other.

Keywords: eye-hand coordination; Trial Making Task; correlation analysis

1 Introduction

In perception and activity tasks, continuous visual tracking of the performed activity requires continuous eye motion. Besides writing and reading, the cooperative work of eyes and hands is a key factor when drawing and at certain motions (e.g. ball catching or throwing); during the exact execution of motions, eye-hand coordination has the utmost importance. In education, its development in different tasks has highlighted significance regarding several subjects. Analyses related to eye-hand coordination problems play a major role in early detection and proper therapy, specification of development.

More and more studies deal with the analysis of human motion. The human motion's image-based computer observation, recording and evaluation provide several opportunities for example in the development of human-computer interfaces [1] [2], in the exploration of certain motion problems, analysis of motions [3] [4] [5], analysis of certain learning processes [6] or even in human-robot cooperation, or robot-based rehabilitation [7].

Humans are able to reach and catch target objects, despite different circumstances, even if the object's position changes. This ability is enabled by eye-hand coordination. The simultaneous studies of eye and hand motions are required to understand this behavior. For example, to continuously and precisely track a moving object or line, the appropriate eye-hand coordination is necessary. In such types of tasks, keeping the look close to the target is important; the stable retina is critical for proper control [8].

The internal process performing eye-hand coordination has a complex control, specified by the complex of cognitive abilities [9]. Eye-hand coordination is such a sensory mechanism that controls eye and hand motions as a single unit [10].

In this paper, the eye-hand coordination is analysed during the Trail Making Test. Trail Making Test is widely used to analyse neurocognitive abilities, and to test normal functions [11]. The test primarily serves as a measure of visual searching or scanning, visuospatial sequencing, although, during its execution, rapid eye-hand coordination plays a key role. [12].

The analysis of eye-hand movements was examined using the gaze and mouse fixations and average gaze mouse path distance while solving the Trail Making Task. The [13] includes the results of descriptive statistics.

2 Eye-Hand Coordination

People have very developed abilities to track and catch moving objects changing their position. This brain-controlled ability is called eye-hand coordination. Eye-hand coordination is a complex process because it includes the visual control of both eyes and hands while using eye movements to optimize vision at the same time.

Eye and hand motion analyses are performed mainly regarding fix position targets, and there are fewer studies regarding moving targets [14]. In certain studies, tracking of moving target with the eye was examined [15], whilst in others, the joint tracking of moving target with the eyes and hands [16].

Three methods are widely used to analyse human motion: passive, wearable detector and the pointer. In the case of the passive solution, the camera is placed in a fix position, usually opposite to the testing subject; thus, the image area is fix [17]. In the case of a wearable detector, the device is attached to the body, which may be even a wearable camera [18] [19] [20]. The pointer approach is based on that we look to the direction where we would like to do something. The eye-tracking method is applicable to monitor the look. In this case, two cameras attached to the head are used, the first camera returns the view seen by its user, while the other monitors the eye motion and determines the look's direction accordingly. Several manufacturers produce such devices to be worn as googles [21].

The eye-hand visual-motoric controlling system implements a closed-loop visual regulation, although such feedforward abilities are required, that help to forecast the motion's track [22]. The internal process performing the eye-hand coordination has a complex control, specified by the complex of cognitive abilities [22]. Eye-hand coordination is such a sensory mechanism that controls eye and hand motions as a single unit. The brain has first to solve the geometric transformation between the world perceived by the eyes and the body-centered world to achieve these motions. Second, the brain has to work out a plan how to reach the object and assess the motoric motion of the hand in the coordinate system relative to the body, taking the information and the hand's actual position perceived by the eyes into consideration [23]. Moreover, during the assessment of the motoric motion, the size, shape, motion, and orientation of the object to be caught must be considered.

No united theory exactly describing eye-hand coordination has been worked out yet, and it is not yet clarified either, to what extent does information stored in the memory participate in motion planning. First, according to studies, the brain uses information that is both continuous visual and stored in the memory, depending on their reliability. If continuous visual information is reliable, then the brain primarily relies on it during motion planning [24]. If the reliability of the continuous visual information is getting worse, then the brain starts using information stored in the memory to plan the motion. In the case of worse visibility, the hand motion becomes uncertain.

From the aspect of eye-hand coordination, the direction of the look’s fixation is a key factor since prior to catching an object, the look is directed onto the object to be caught for a longer period [25]. Fixations are stable fixed right until catching the object; however, fixations directed to the object are no longer necessary then.

Accordingly, fixations have a triple role in motion planning:

- different fixations are necessary to map the environment and to determine the position of the object to be reached;

- based on the fixations in the right points, and their sequences, the brain is able to assess the human body's coordinate system relative to the world's coordinate system [25];
- The brain stores the position of the detected objects in the memory and the sequence of positions recorded during fixations, thus enabling motion planning depending on the task to be achieved.

3 Trial-Making Test

Trail Making Test (TMT) one of the most widely used tools of neuropsychological examinations. The goal of TMT is to check the visual attention, the processing speed, visual searching, analysis of motoric performance and fast eye-hand coordination. [26] [27] [28].

The PEBL (The Psychology Experiment Building Language) version of the test consists of three parts that must be executed as quick and accurate as possible. During the TMT-A1, 25 randomly assorted numbers must be interconnected in increasing order (1–2–3–4, etc.) (Fig. 1) and similarly with the sequence of the letters (A-B-C-D, etc.) in TMT-A2. TMT-A measures visual attention and scanning, and speed of eye-hand coordination. In the TMT-B, similarly, but the numbers (1–13) and letters (A–M) alternate sequentially (1–A–2–B–3–C, etc.) (Fig. 2). TMT-B additionally, assesses working memory and executive functions. The results of each part are determined by the TMT test solving time and errors. The test solving time expresses the result of visual attention and scanning because the errors in select next cell increase the time of solution.

The Trail-making task's PEBL version is able to run the test according to ‚retain original configuration [29], and new tests generated during each new running, although the application of automatically generated tasks is recommended since it enables partial examinations.

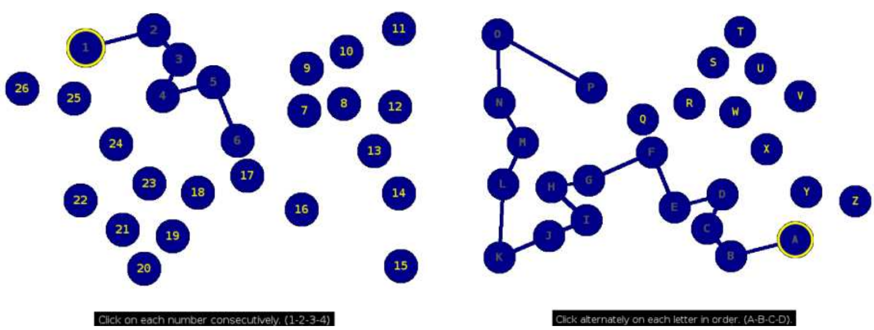

Figure 1
PEBL Trail Making Task Test A1 and A2

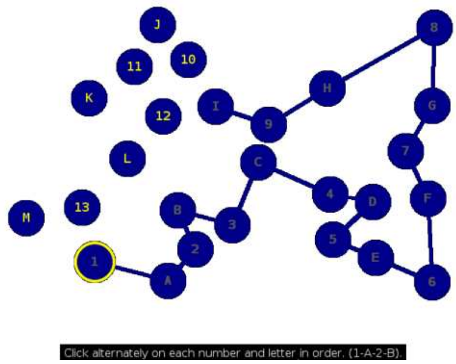

Figure 2
PEBL Trail Making Task Test B

4 Eye and Mouse Cursor Tracking

The recording of the eye movement was made using a GP3 Eye Tracker (Fig. 3), which has 0.5-1° view angle accuracy, 60 Hz sampling, and is appropriate for general research purposes. The recording and analysis of eye and mouse motion parameters were made using the OGAMA (OpenGazeAndMouseAnalyzer) software. The application records the eye and mouse cursor trail in a database and determines the specific parameters of the motion, and provides other evaluation opportunities too.

Figure 3
Gazepoint GP3 Eye Tracker

5 Methods

5.1 Participants

Eleven men and eight women participated in the TMT - Eye-hand coordination test on a voluntary basis. Their age varied between 10 and 70 years. The age and gender distribution of testing subjects are listed in Table 1.

Table 1
Participants

Age	**Number of test subjects**	
	Male	***Female***
10-20	1	1
20-30	3	2
30-40	3	2
40-50	2	1
60-70	2	2
Total	**11**	**8**

5.2 Procedures

During the performance of the PEBL Trail-making task, the eye-tracking system and OGAMA software were applied to record eye-hand coordination data (Fig. 4). During the test, using the Gazepoint Control software establishing communication with the GP3 eye tracker, and the gaze and mouse path was recorded by OGAMA software after the calibration process, thenfurther statistical analysis was performed following the tests. The eye and mouse movement was recorded separately during the three partial tests. The data analysis was carried out offline by statistical methods.

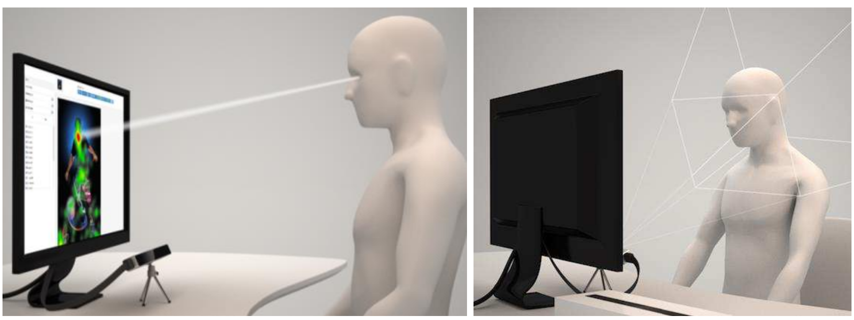

Figure 4
Eye-tracking setup [?]

5.3 Analysis

The variables: gaze fixations, average gaze mouse path distance and mouse fixations are examined because mainly, these parameters are related to eye-mouse motion features in the coordination. These parameters are the dependent and the duration time of the Trail Making Task is the independent variable. These parameters are measured at the ratio level.

The linear relationship is assumed between these examined variables and was examined by scatterplots. Scatterplot was used to plot the dots of examined variables, and then visually inspected the linearity showing the Fit Line in the scatterplots. Outliers are checked using Box plots. Normality is examined of each variable separately by Shapiro-Wilk test and Q-Q plots. In the case of a normally distributed variable, the Pearson correlation is used, if not, the nonparametric Spearman correlation is applied.

6 Results

The next chapters summarize the quantitative results of statistical correlation analysis of gaze and mouse tracking parameters while solving TMT-A1, TMT-A2 and TMT-B tests. The results of the three main steps are summarized: investigation of the linear relationship and outliers; normality test; results of Pearson or Spearman correlations.

However, it should be mentioned that OGAMA software also provides the opportunity to conduct qualitative tests, for example, attention map or scan path of gaze or mouse cursor motion (Fig. 5).

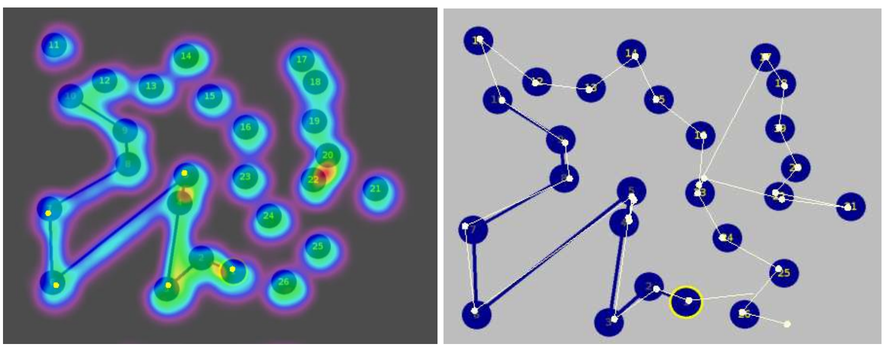

Figure 5

Example gaze attention map and scan paths of mouse cursor while solving TMT-A1 [?]

6.1 Correlation Analysis for TMT-A1 Task

6.1.1 Investigation the Linear Relationship and Outliers of TMT-A1 Task

Fig. 6 shows the scatter plots of gaze fixations count, average gaze mouse path distance and mouse fixations count. As shown in the plots, the gaze and mouse fixations counts are in a linear relationship with TMT-A1 Task solving time, but average gaze mouse path distance dots do not fit a line. According to Box plots (Fig. 7), the results of Test subject 13, 18 and 19 consists outliers (showing "*") which should, therefore, be ignored in further analysis.

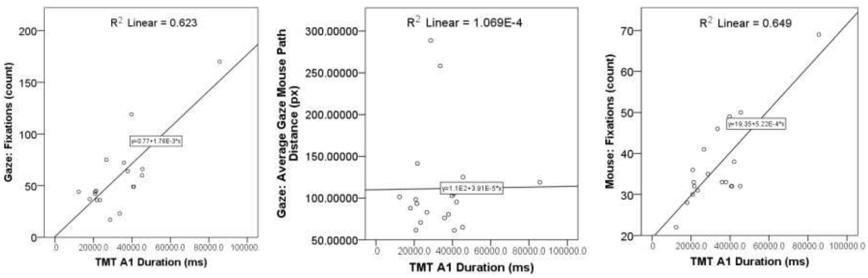

Figure 6

Scatter plot results of TMT-A1 gaze-mouse parameters

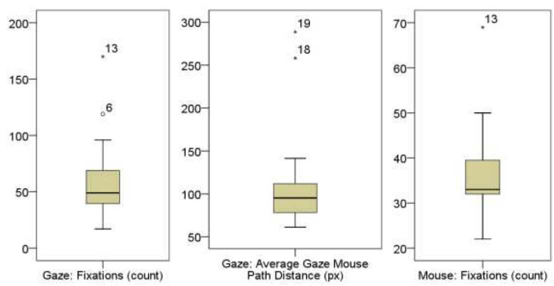

Figure 7

Box plot results of TMT-A1 gaze-mouse parameters

6.1.2 Normality Test of TMT-A1 Task

Fig. 8 shows the Q-Q plots of the examined gaze fixations count, average gaze mouse path distance and mouse fixations count parameters. The values do not fit well on the line y=x, so the normal distribution is not approximated for gaze and mouse fixations; however, it can be approximated for average gaze mouse path distance. The quantitative results in Table 2 confirm this statement because the Sig. of Shapiro-Wilk test is less than 0.05 for gaze and mouse fixations.

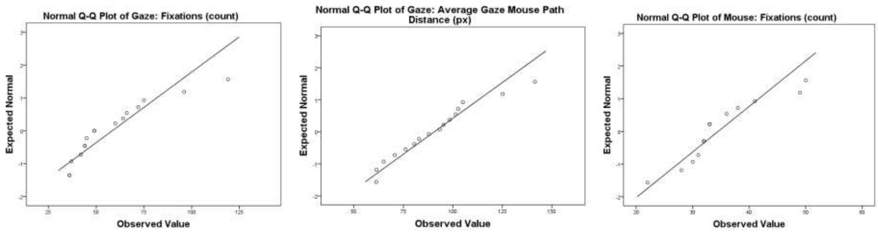

Figure 8

Q-Q plots of TMT-A1 gaze-mouse parameters

Table 2

Tests of Normality for TMT-A1 gaze-mouse parameters

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Gaze: Fixations (count)	.219	16	.039	.850	16	.014
Gaze: Average Gaze Mouse Path Distance (px)	.133	16	.200*	.945	16	.419
Mouse: Fixations (count)	.270	16	.003	.875	16	.032

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

6.1.3 Correlations of TMT-A1 Task

Based on the results of the normality test Pearson correlation is calculated for Average Gaze Mouse Path Distance, and Spearman correlation for gaze and mouse fixations while the independent variable is TMT solving duration time (Table 3).

Table 3

Correlations of TMT-A1 gaze-mouse parameters

		Gaze: Fixations (count)	Gaze: Average Gaze Mouse Path Distance (px)	Mouse: Fixations (count)
TMT Duration (ms)	Correlation Coefficient	.571*	.194	.508*
	Sig. (2-tailed)	.013	.456	.031
	N	18	17	18

*. Correlation is significant at the 0.05 level (2-tailed)

The value of correlations showing medium correlation and significant relationship for Gaze (r = .571, n = 18, p = .005) and Mouse Fixations (r = .508, n = 18, p = .005) which is statistically significant and smallweak relationship for Average Gaze Mouse Path Distance (r = .194, n = 17, p = .456).

6.2 Correlation Analysis for TMT-A2 Task

6.2.1 Investigation the Linear Relationship and Outliers of TMT-A2 Task

Fig. 9 shows the scatter plots of gaze fixations count, average gaze mouse path distance and mouse fixations count. As shown in the plots, the gaze and mouse fixations counts are in a linear relationship with TMT-A2 Task solving time, but average gaze mouse path distance dots do not fit a line. According to Box plots the results (Fig. 10) of Test subject 18 and 19 consists outliers (showing "*") which should, therefore, be ignored in further analysis.

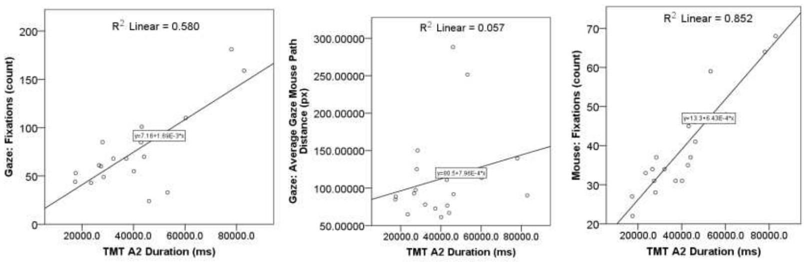

Figure 9

Scatter plot results of TMT-A2 gaze-mouse parameters

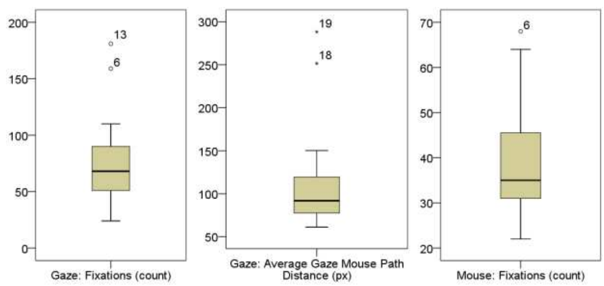

Figure 10

Box plot results of TMT-A2 gaze-mouse parameters

6.2.2 Normality Test of TMT-A2 Task

Fig. 11 shows the Q-Q plots and normal distribution is not well approximated for gaze and mouse fixations; however, it can be approximated for average gaze mouse path distance. The quantitative results in Table 4 confirm this statement because the Sig. of Shapiro-Wilk test is less than 0.05 for gaze and mouse fixations.

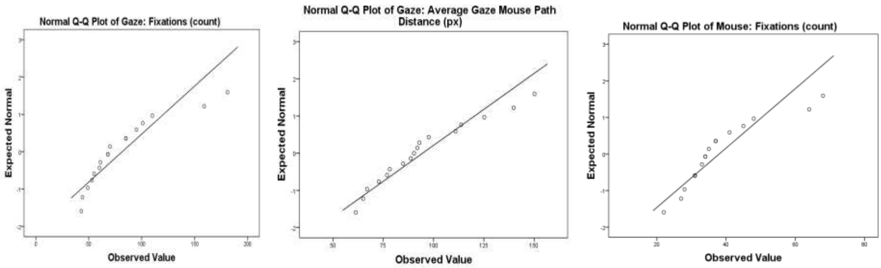

Figure 11

Q-Q plots of TMT-A2 gaze-mouse parameters

Table 4

Tests of Normality for TMT-A2 gaze-mouse parameters

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Gaze: Fixations (count)	.206	17	.055	.834	17	.006
Gaze: Average Gaze Mouse Path Distance (px)	.171	17	.198	.929	17	.211
Mouse: Fixations (count)	.238	17	.011	.848	17	.010

a. Lilliefors Significance Correction

6.2.3 Correlations of TMT-A2 Task

Based on the results of the normality test Pearson correlation is calculated for Average Gaze Mouse Path Distance, and Spearman correlation for gaze and mouse fixation while the independent variable is TMT solving duration time (Table 5).

Table 5

Correlations of TMT-A2 gaze-mouse parameters

		Gaze: Fixations (count)	Gaze: Average Gaze Mouse Path Distance (px)	Mouse: Fixations (count)
TMT Duration (ms)	Correlation Coefficient	.537*	.227	.892**
	Sig. (2-tailed)	.018	.382	.000
	N	19	17	19

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The value of correlations showing medium correlation and significant relationship for Gaze (r = .537, n = 19, p = .018) and high correlation, strong relationship for Mouse Fixations (r = .892, n = 19, p = .000) which is statistically significant and small relationship for Average Gaze Mouse Path Distance (r = .227, n = 17, p = .382).

6.3 Correlation Analysis for TMT-B Task

6.3.1 Investigation the Linear Relationship and Outliers of TMT-B Task

Fig. 12 shows the scatter plots of gaze fixations count, average gaze mouse path distance and mouse fixations count. As shown in the plots, the gaze and mouse fixations counts are in a linear relationship with B Task solving time, but average gaze mouse path distance dots do not fit a line. According to Box plots, the results (Fig. 13) of Test subject 19 consists of outliers (showing "*") which should, therefore, be ignored in further analysis.

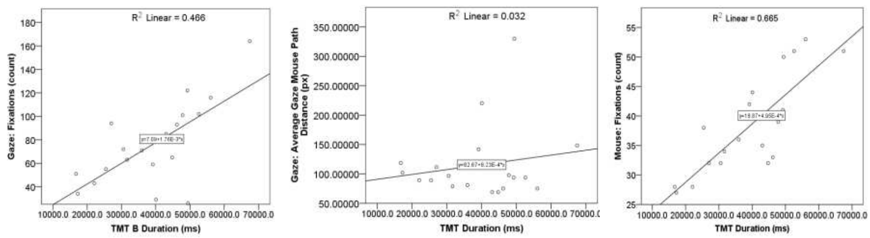

Figure 12

Scatter plot results of Trail Making Task B variables

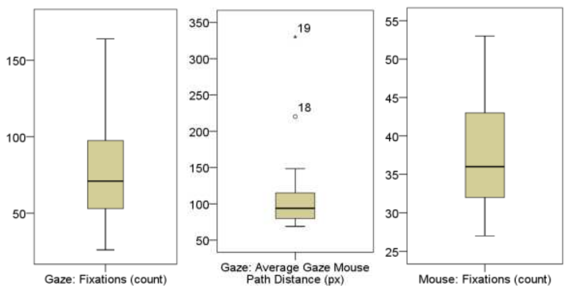

Figure 13

Box plot results of Trail Making Task B variables

6.3.2 Normality Test of TMT-B Task

Fig. 14 shows the Q-Q plots and normal distribution is approximated for gaze and mouse fixations; however, it can not be approximated for average gaze mouse path distance. The quantitative results in Table 6 confirm this statement because the Sig. of Shapiro-Wilk test is less than 0.05 for the average gaze mouse path distance.

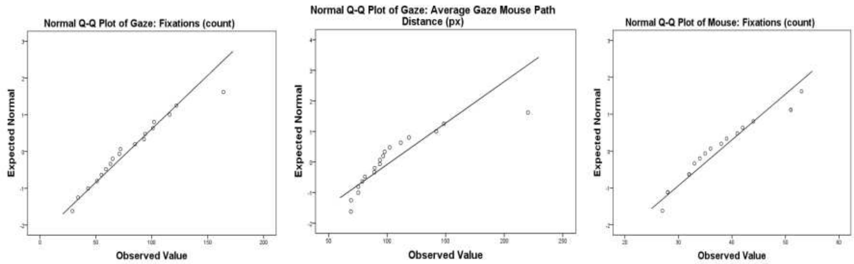

Figure 14

Q-Q plots of Trail Making Task A2 variables

Table 6

Tests of Normality for TMT-A2 gaze-mouse parameters

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Gaze: Fixations (count)	.134	18	.200*	.957	18	.548
Gaze: Average Gaze Mouse Path Distance (px)	.231	18	.012	.778	18	.001
Mouse: Fixations (count)	.132	18	.200*	.919	18	.126

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

6.3.3 Correlations of TMT-B Task

Based on the results of the normality test Spearman correlation is calculated for Average Gaze Mouse Path Distance, and Pearson correlation for gaze and mouse fixation while the independent variable is TMT solving duration time (Table 7).

Table 7

Correlations of TMT-B gaze-mouse parameters

		Gaze: Fixations (count)	Gaze: Average Gaze Mouse Path Distance (px)	Mouse: Fixations (count)
TMT Duration (ms)	Correlation Coefficient	.683**	.164	.815**
	Sig. (2-tailed)	.001	.515	.000
	N	19	18	19

**. Correlation is significant at the 0.01 level (2-tailed).

The value of correlations showing medium correlation and significant relationship for Gaze ($r = .683$, $n = 19$, $p = .001$) and high correlation, strong relationship for Mouse Fixations ($r = .815$, $n = 19$, $p = .000$) which is statistically significant and small relationship for Average Gaze Mouse Path Distance ($r = .164$, $n = 18$, $p = .515$).

7 Discussion

The rapid execution of the Trail Making Task that affected the test time and served as the independent variable of the test mainly depends on the visual attention and rapid and quick eye-hand coordination. Since the quick solution of the task depends on the visual searching, the precise and rapid motion of the look from the fixation directed onto the next target to the mouse cursor target, the test was aimed on the evaluation of this activity. In the execution of the appropriate task, the coordination of eyes and hand depends on the visual attention, search, primarily the number of the look's fixation and moving the mouse cursor into position quickly and precisely, the test primarily focused on them, to analyse the fixations as targets, and on the average distance regarding moving of the look relative to the mouse cursor. By the post-processing of eye motion and mouse cursor motion recorded during the execution of the three versions of the Trail Making Task, the aforementioned parameters were received. Based on the results, the eye movements and the mouse cursor motion's fixation number is in medium or strong relevance with the test's execution time, which was proven to be significant. Since there is an opposite relationship between the test's execution time and the level of visual attention, the fixation numbers negatively correlate with visual attention. These results refer to that by more efficient visual attention, quicker visual searching, the shorter task execution reduces the number of fixations of both eye motion and mouse cursor movement, so the look is quickly directed to the next target without recording intermediate points. In case of the distance between the look and the mouse cursor, however, a negligible correlation was experienced, meaning that the trail of the look and the mouse cursor compared to each other does not significantly depend on the visual attention level and the searching agility. Relative to the look's faster or slower motion; the mouse cursor moves in similar speed, so closer visual attention, quicker visual searching, the eye's more purposeful motion involves the quicker and more precise motion of the mouse cursor, i.e. the hand. Based on this, the agility of the eye-hand coordination is in a positive relationship with visual attention, so these factors correlate with each other. For the future, it is also appropriate to examine how age influences the results.

Conclusions

In this paper the visual attention and hand coordination was examined by analyzing certain features of eye- and computer mouse cursor motion. Based on the statistical correlation analysis results of data, it was determined, that the fixation parameters of eye and hand motion are in negative correlation with visual attention, while the distance between the look and the mouse cursor's motion are not correlated to each other. Visual attention and proper eye-hand coordination have key significance from the aspect of the proper execution of several human activities like tool usage, manual machining for example; thus the recognition of potentially occurring coordination problems, its development, reduction of problems are all important factors. The results may help to detect eye-hand coordination problems, which may be the cause of problems occurring in writing and drawing abilities, this helping to specify the necessity of eye-hand coordination development. According to the above, the development of eye-hand coordination plays a key role in education too, regarding several subjects, i.e. writing, drawing, technique and lifestyle, and of course, at complex motion sequences. Modern infocommunication tools play an even more significant role in supporting education [30]-[35], where eye-hand coordination is important factor such as gamification [36], VR based education [37]-[43] project-based teamwork [44] or other visual, interactive systems [45]-[49].

Acknowledgement

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E-learning Spaces to Empower Students Collaborative Work Serving Individual Goals

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Abstract: Innovation has an impact on modern society, so it appears as a demand of the learning society in the educational process. However, there are many other factors that need to be taken into account in supporting an individual's success in designing and implementing a learning process, not just technological change. As opportunities are multiplied, technological support for collaborative work is becoming increasingly demanding to effectively utilize these opportunities in everyday student work. The aim of higher education is to support student success. The continuous adaptation of educational environment to student needs is an important element of this need.

Keywords: elearning environment; collaboration; innovation

1 Strategic Educational Aspirations of Hungary in the Spirit of Innovation

Internationally, the OECD[1] prepared and published a study in 2010, "The Nature of Learning: Using Research to Inspire Practice", which contains the basic principles of the learning environment specifically in the educational sense. [1]

The principles emphasize the personal, inclusive and community nature of the environment to be established, as well as its learner-centered and structured nature. Based on these principles, Hungary released its Digital Education Strategy. According to the Digital Education Strategy issued in the Digital Welfare Program framework in Hungary, in line with the strategy of “Change in Higher Education,” Hungarian higher education develops a uniform online digital environment which offers personalized learning opportunities, tailored to individuals interests and life situations. An online learning space was established and also a learning community where community members are supported in their lifelong learning and self-development.” [2]

[1] OECD = Organisation for Economic Co-operation and Development

While "The vision of public education concerns a high-quality and equitable public education system that prepares young people -who would be capable of adapting to the social and economic spheres of Europe and the world- for the labor market, higher education, and lifelong learning." As an intervention area, the government indicated that "information retrieval, processing, the use of collaborative ICT-supported solutions and media awareness should be built into students' learning tasks. The practical application of ICT should be embedded in the acquisition of science subjects through digital sensor-based measurement, data processing, evaluation and visualization (such as 3D printing)." [2]

The role of higher education in the high-level training of future generations is crucial. With the use of tools and methods that support training, the institutions strive to change in line with the results of scientific research and development to adapt to the process of innovation.

2 Higher Education Efforts to Support the Goals of Educational Strategy

In the field of higher education, there is a strong desire to create a learning environment that is tailored to student needs. This process is permanent and the environment itself is dynamically changing through the use of disruptive[2] technologies. Student needs show a high degree of technological commitment. This characteristic is mainly manifested in the definition of the way of searching/gathering, processing information and content-generating. A common feature of the learning community is that they are extremely adaptable to innovation trends, able to immediately adopt and use emerging technologies, well-come their disruptive feature. They are technologically committed, instant feedback is important during their work, and they prefer short text and large amounts of audio-visual content. [3] They like to work in teams, have a strong sense of community. The sense of belonging to the community enhances the sense of self-confidence as they enjoy the support of the community. [4]

The digital education strategy defines the educational environment in several aspects. In this study, we examined online collaboration from the many aspects and examined its significance at the University of Dunaújváros.

[2] disruptive = "creative destruction"

2.1 Former Research Results in Serve of Further Development

In our previous study, which focused on the relationship between the individual and the community, we explored the necessity of expanding the learning space from this aspect. Based on the results, it can be stated that students are very keen on existing in the online environment during their learning process, regardless of the type and form of work they do. To achieve a more nuanced picture, further research shows that an e-learning environment (e.g. the Moodle) is more suitable for student-teacher communication (and of course cooperation) rather than peer-to-peer communication. It is also true that communication with peers is more likely to take place in an online environment (e.g. Facebook group) than face to face. Observation of student activities leads to the conclusion that the individual requires collaboration with peers, but the ability to collaborate if they have an educational goal that is strongly influenced by the nature of a certain subject.

In this study, we focused on student activities in subjects requiring different forms of work, with a particular focus on learning activities in the online environment. Determining the conclusions of the study, student effectiveness played the main role.

2.2 Innovative Tools and Methods

The use of innovative tools and methods actively contributes to the success of the learning process. Supporting, developing, extending all of these into the virtual learning environment is an important factor in the teaching process. In order to support student success in higher education, various disruptive innovative technologies and pedagogical methods are used to obtain and process information and generate knowledge.

In the system of efficiency, effectiveness, and success in the field of education, the development of a learning environment plays just as important role as the appropriate method of teaching, the way in which learning is organized and supported or the strategy. [5] [6] Many previous research have dealt with studying the learning environment, developing innovative learning environments to make learning effective. [7] [8] [9] [10] [11]

The technological changes that spill over into the field of education are creating the conditions in which the "creative destruction" is finding its way. Typically, the result of this process is a change in the technology of education, in line with modernization, the incorporation of new technologies and methods into the educational process. Innovative methods that break with traditional, well-established practices and use modern tools can stimulate participants in the education process, thus facilitating the accumulation of human capital, ie abilities and skills. [12] [13]

2.3 Applied Forms of Work in an Effective Learning Environment

This study presents the results of our research on learning organization, focusing on different forms of work, in order to make learning successful. One of the most significant features of constructivist pedagogy is effective learning organizing method. The modern ICT and CogInfoCom supported education [14] [38] has several additional benefits and possibilities to improve the learning effectiveness like Virtual Reality-based learning spaces [15, 16, 17] and virtual labs [18], serious games, gamification or team-based collaborative education [19], [20], Human-Computer Interfaces [21, 22, 23] and other educational environments [24, 25, 26, 27].

In traditional “frontal” classwork, the teacher is an active source of knowledge and the student is a passive learner with very little interaction. In contrast, to this, in an effective learning environment, classical transferring and receiving roles cease, the student becomes active, the amount of interaction increases, and the student can now be a source of information and knowledge transfer. In this learning environment, students can collaborate with one another in a variety of forms of work and help each other with their work through a variety of methods and tools.

However, when choosing the form of work to be used, the particular educational objective must be taken into account, since each form of work has different advantages and disadvantages and promotes the development of different fields.

One type of traditional mode is frontal classwork, which has the advantage that an information source can transmit information to a large mass of people at the same time and in one place. Teacher explanation thus facilitates understanding, develops attention and concentration. Typically, it is well suited for communicating new knowledge, general definitions, regularities, and facts. Of course, this form of work can be effectively transposed into an innovative learning environment through video conferencing, webcasting, or even virtual lectures. The space in this sense is the electronic environment, the virtual space.

Another form of a traditional learning organization is individual student work. It has the advantage of allowing a better and deeper understanding of the trainee's individual qualities and allows for individual treatment, as well as enhances the ability to highlight and develop autonomy. [28]

Effective learning methods include pair work, teamwork (which can be a task solution or experiment) and teamwork around project tasks. The advantage of each form of work is that it encourages cooperation, improves helpfulness, tolerance and conflict management. However, debates and the possibility of division of tasks can turn the advantage into a disadvantage, debates can escalate because students are unable to work properly and reach consensus, attention can be misaligned, and responsibility can be weakened. [29]

Still, there are many forms of work that help the student, including individual and teamwork. These are becoming more and more widespread, hence these two forms of work are at the heart of our investigation. According to scientific researches, one of the characteristic features of Generation Y, who is extremely committed to modern technology in higher education, is that they prefer teamwork and collaboration to work individually. [30]

3 Aims and Methods of the Research

In our research, the focus was on applicable forms of work in learning process to achieve success and quality.

We have chosen a popular form of empirical research, the questionnaire. According to the scientific approach, the student community serving as the core population of our study was a group of students with active student status in higher education who already fully "speak" the language of today's information society, so electronic questionnaires have proven to be the most appropriate means of interviewing.

The University of Dunaújváros is a modern technical university, which provides study programs taught in English language for international students from four continents. In the case of a project-based subject (*Project Management and Practice*) we have choosen the interview as a more direct method of questioning. In addition, foreign students fulfilled a self-reflection questionnaire at the end of the semester. Open-ended questions were applied during the interview face-to-face and the electronic self-reflection questioning. We summarized the results of foreign students' questioning in a case study.

We used the random sampling method. The questionnaire was completed using the self-completion method, which has the great advantage that there is no questioner bias.

The numerical data of the received answers were processed with the Excel spreadsheet program of Microsoft Office suite. For open-ended questions, we conducted a content analysis.

Student activities were observed in four subjects (*Informatics, Internet Technologies, Project Management and Practice and ERP Systems*) that required the use of two different forms of work.

- The topics of *Informatics* and *Internet Technologies* are designed so that they allow individual student work, require autonomy and self-discipline, enable self-direction, rather than require cooperation or collaboration.

- The curriculum of *Project Management and Practice* basically prefers teamwork as an applied method, as students work together in teams to design a long-term solution to a chosen task and to achieve a predefined goal according to a specific set of requirements.
- *ERP Systems* helps the practical application and acquisition of knowledge by carrying out a project assignment on the one hand and by completing a project task on the other.

4 Results

Our study focused on three areas: we drew conclusions by analysing basic statistics, device usage, and a questionnaire of teamwork.

4.1 Questionnaire of Device Usage

The first group of questions connected to general statistic information. In the summer of 2019, 58 students of the four subjects mentioned above were randomly interviewed. Given that three of the subjects are included in the curriculum of the IT profession where men are over represented, it is not surprising that they account for 70% of the respondents.

In the composition of the participants according to their study program, the highest proportion was Computer Science Engineering (43%), one third Mechanical Engineering, 14% Business Administration and Management students, other Communication and Media, Technical Management or Teacher of Engineering. Three-quarters of the sample student population takes part in bachelor, 20% in higher-level vocational training and only a small proportion studies on master level. Regarding the work schedule, the distribution has shifted to part-time students, with two- thirds of respondents attending part-time training and one-third attending full-time training. The answers of the first and second-year students dominated, with 70% of the sample.

The second group of questions was connected to the use of devices. In this group of questions, we were curious as to know how typical is the innovative technologies in students' device usage, and how often they appear in their everyday lives, especially in their learning processes.

The digital world is already a natural medium for Generations Y and Z [32], so it is not surprising that almost all respondents have a computer or laptop (93%). Nowadays, owning smartphones is also common in this age group, and this has returned in the answers, with 93% giving a positive answer. Nowadays, much fewer people own smart watches (19%), video game consoles (29%), drones (5%), VR glasses (2%, or 1 person). (Figure 1)

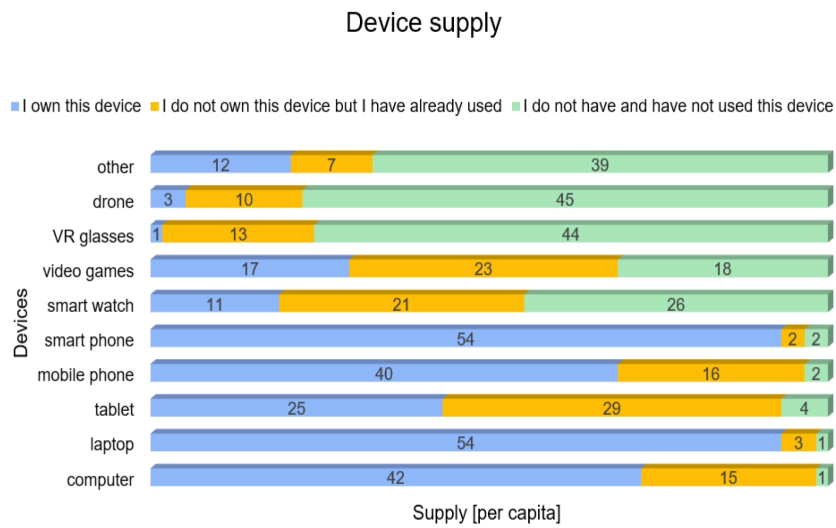

Figure 1

Innovative device supply (per capita)

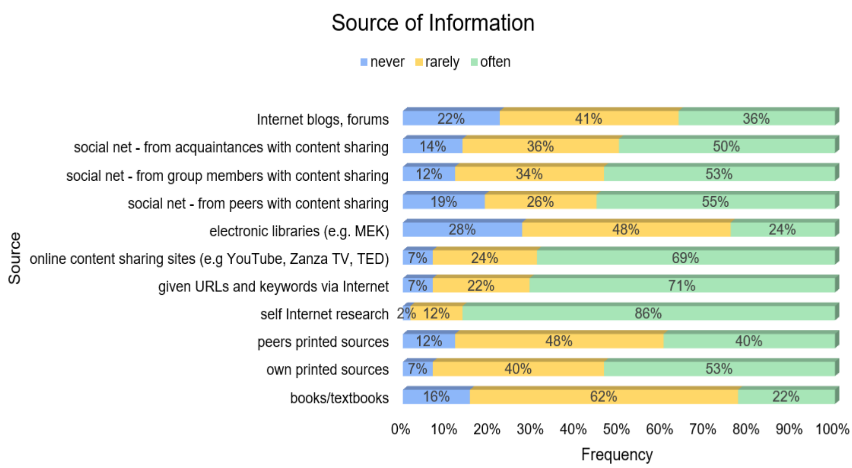

Figure 2

Source and frequency of information gathering

In this group of questions, we also examined where students learn about the curriculum and how they prepare for the examinations. The use of textbooks and electronic libraries is hardly typical (about 20-25% of students chose the "often" option). According to half of the sample, printed notes owned by the students and social networking sites are used to obtain information. It shows that social media significantly determines the available knowledge and influences the students' relationships in the online space, and in an effective way facilitates learning by implementing cooperation. Slightly less is learned from blogs, forums, and peer-reviewed notes (35-40%). More popular are self-researched items (86%) or URLs given by others (71%), online content sharing sites (69%), which indicates that they prefer using material on the World Wide Web to traditional books. (Figure 2)

The importance of digital curricula is also illustrated by the fact that while 60% have labeled textual content as the most typical source, 34% are already looking for video content.

4.2 Questionnaire of Team Work

The third group of questions is related to teamwork. With this set of questions, we sought to explore how students relate to two radically different forms of work. At the individual level, we were able to look at the issue from specific perspectives, where we first sought to find out how useful the teamwork approach was for the students to learn the subject matter. Another set of questions provided a more nuanced picture of the students' subjective opinions, their feelings about the forms of work, and their attitude towards collaboration.

Only 16% of the surveyed students indicated that they had not worked/studied in any form of collaborative work, so we can conclude that they usually have some experience with social work (i.e. team, group or pair work). The picture is further blurred by the fact that 59% of them have already taken part in teamwork, which is a higher level of collaboration, so their opinions are based on real experiences and are well-founded.

78% of the sample included *Informatics*, 48% *Project Management and Practice*, 36% *Internet Technologies* and 19% *ERP systems*. In the acquisition of Informatics, respondents rated the usefulness of teamwork on a scale of 1 to 5 on average as 3.1. Considering that there is only individual curriculum processing in this subject, it is thoughtful whether some common work might have to be introduced or modified in the future. In the case of *Project Management and Practice*, which prefers teamwork, the average of 4.1 also shows that the direction is right. In the case of *Internet Technologies* requiring autonomy, respondents also chose their current work format, with an average answer of 1.7. Also in the case of *ERP Systems*, where the application of self-learned curriculum in practice through collaboration should be synthesized, the 3.8 average of the answers does not justify any reconsideration yet. (Table 1)

Table 1
The importance of teamwork in different subjects

Name of subject	Average of the usefulness of team work
Informatics	3.1
Project Management and Practice	4.1
Internet Technologies	1.7
ERP Systems	3.8

4.3 A Case Study of a Team Work by Foreign Students in the University of Dunaújváros

Project Management and Practice subject is also available for foreign students at the Universtiy of Dunaújváros (UOD) and moreover it is cumpulsory for students in the bachelor program of Computer Science Engineering. This case makes collaboration more exciting because of the varied national characteristics, linguistic diversity. The age match and the distance from their home points towards the frequent use of ICT devices and the permanent online exist.

In the case of foreign students, we applied face-to-face interviews and constant monitoring of the teamwork during the semester of *Project Management and Practice* subject. This period lasted 10 weeks with hard work during that time the team reached the top and delivered the finished product from an idea through initiation, planning, execution and closing under constant control. The team had to create several documents during the process: Initiation document, status reports, project software plan, final documentation, individual report (self-reflection), report of team work. Constant monitoring realized via electronic learning environment (Moodle) as assignments. The responsible person changed according to the certain task: each team member, team leader, a team member recommended by team leader, etc. Each monitoring checkpoint had a strict deadline so every team member were involved to work on their part of the project constantly. At the end of the semester as the closure of the project, the team presented their project process focusing the essential elements of project management: tasks, times, sources, costs. The results were displayed by MS Excel and MS Project charts, tables in MS PowerPoint presentation, the documentation and reports were created by MS Word saved as PDF.

4.3.1 Students' Activities – at Once in Real World

For the first time in the first lesson, every student gathered at the same place in the university, where they could get acquainted and the teacher could familiarize the project and the tasks to them. As the students had not met before and they just got a semester-long task to collaborate, they continued the meeting after the first lesson. They sat around a table of a cafe and discussed the first steps of managing a project.

Fortunately, they could pick a topic, that suited all the members of the team easily as it was a website development titled „The World" Restaurant Ordering Service. The project was about an online restaurant where people could browse the pages to select national dishes of different countries, which were to their liking. If they think they have chosen everything they want, they could make an order. The team had 6 members from different countries of the world.

The team leader was selected based on their personal intuition of the first meeting. The most powerful, best speaker, and bravest student became the team leader who was willing to take the lead and overall responsibility.

During the first meeting, not only the task was selected, but roles were also assigned, taking into account the strengths of the members.

4.3.2 Students' Activities - Online

On this occasion, they also agreed that they would use the online environment to keep contact and share their ideas, documents, contents or ask for help.

- One of the most common social network (Facebook) turned out to be one of their choosen online enviromments. The messaging app and platform (Messenger) of this site was used for rapid message exchange as they could connect with each other instantly and constantly.
- Another website that provided them a quick and easy way to run their own team project was Google Site. This technology tool was useful for project management as it included the essential components: „Home" page: they could give basic information connected to the project (the name, its aim, etc.), „Project at a Glance", „Project Objectives", „To Dos", „Calendar", „Files and Project Documents", „Project Discussion", „Comments and Questions". Every member could make record, set assignments, upload files and discuss what to do next, etc.
- The electronic learning environment of the university was useful for them to gain the relevant information for their teamwork, get the right help at the right time, and to be guided on the side.

To maximize efficiency, each task was assigned to someone who was routine in that area. The motivation of the team also contributed to the success. The team leader reported regularly to participants so he was always aware of the pace of progress and was able to reallocate resources immediately when someone needed help.

4.3.3 Device Usage and Teamwork from the Aspect of Communication

Communication is one of the main cornerstones and components of teamwork.

- Several channels were used for communication between members: in addition to weekly personal meetings, they kept in touch via email, Facebook, phone (it means smartphone in their case) and Google Site as well.
- Students had to create 5 written reports during the process (a Project Initiation Document, 3 status reports, and Final Documentation), which was uploaded to Moodle and evaluated there as well.

However, in addition to making it easier for them to follow their own work, they also prepared a memo for each meeting (even more of them), that were attached to the final documentation. The team set their necessary inside communication plan with regard to linguistic diversity and the theme novelty.

4.3.4 Device Usage and Teamwork from the Aspect of Gathering Information

Gathering information seems as important as communication in the lifeline of the project.

- The first channel of information gathering was the Internet.
- On the next level came a narrow layer of the foreign community of UOD to expand the first version with useful comments and opinions. On this level, the questioning took place both face to face in the dormitory, school, and cafes and online as Messenger and Facebook shared questionnaire.
- On the third level, in addition to university peers, the website was tested with the members' acquaintances back at their home country (family, former high school peers, friends) to gather information to improve the finished product based on feedback received. The students were enthusiastic about the bugs, enjoyed the game, and many showed interest in both program development and design, it could say that the task has taken on an international dimension of its kind.

Successful mixing of the different work forms in the learning process is not unique among the students of higher education. According to a study of K. Erdélyi "At Óbuda University the best practice in international groups is that group activities and alone work take turns so each student gets the opprotunity to do in which he is the best." [31]

4.3.5 The General Feedback of the Team Members

At the end of the semester in time of project closure team members were asked to prepare a self-reflection of their own work. One part of this essay refered to the communication among the members with the following questions:

- With who did you communicate?
- When and how long did it take?
- How did it happen (what channel)?
- What kind of information did you exchange?

Normally all of them communicated with the whole team during the process. If their tasks connected to a certain team member's task, they had small chats only between them.

The length of communication depended on the depth of the problem or the quiz of the next step. It took from 10 minutes long up to three and a half hours. The frequency of communication was various from occasional, through once in two weeks to every week or daily.

According to the way of communication, the student's answers were distributed equal proportions in roughly between face to face-and-online. The favored online form of communication was chat in Messenger, but Skype calls and emails were also very determinative.

The nature of the communication was discussion, information/content exchange, giving advice, giving a helping hand, problem-solving. Unfortunately not every team meeting was productive, as they looked back, they would change the frequency and organization of the communication.

Altogether all the members left the class with the same satisfying feeling as though they had a lack of their own preformance as they could not do everything like they expected, but the participation in the team was really good. The deadlines of work were respected by them, the team mates were all cooperative and comprehensive.

As the members reflected, they acquired a knowledge of several different subjects and developed some important skills such as: communication and negotiation, problem-solving, critical thinking, device and software usage and navigation among different platforms in the electronic environment.

Working on the project in general also helped them to develop such personal skills as planning, time managing, self-managing and relation building.

5 Evaluation of the Results

Within the basic statistical questions group, we asked the admission score and whether the respondent has high-school graduation in ICT field because personal motivation is an important factor in increasing success and efficiency. More than 50% of the respondents have a high-school education in IT (intermediate or advanced level or have taken a professional IT high-school education exam), but half of them did not remember the result of the admission, so the answer to this question greatly distorts the analysis, hence we could not draw conclusions.

One of the aims of our research in the tool use issue question group was to compare the use and frequency of using tools, thus exploring the spread of disruptive innovative technology. We found that 74% of both PC and laptop owners use their device at least once a day in the sample, and we found almost the same results with smartwatch owners (72%). However, smartphones are used at least once a day by 96% of the sample. Less common devices are used less frequently by their owners: 12% of the sample said they use gamer consoles daily and 33% of the sample said they use drones weekly. We also found a surprising result in this issue: a student wearing VR glasses uses them every day.

When analysing the answers to the question about the source of knowledge, it became evident that the group of students in the current higher education needs collaboration, as more than 50% of the respondents often visit their social networking sites for information from their peers (55%), other group members (53%), acquaintances (50%), and through various forums, including strangers (36%).

Analysing the answers to the questions of the teamwork group, we also got an interesting result in the light of our previous findings, when the effectiveness was also examined. As an example, we investigated the grades of two courses of the semester 2017/18/2. The average subject grade in *Informatics* was 4.06 (with a negligible difference between the two courses). So, traditional, customized curriculum processing seems to be a completely appropriate method. Regarding the subject of *Project Management and Practice*, a very high average score was found (4.22), but here the part-time students did even better, their average was 4.58. The research did not explain the reasons for the difference; however, we assume that not only their high motivation level but also the greater practice working with peers could be the reason for the success.

We also examined students' perceptions of the advantages and disadvantages of teamwork. They had to mark the truthfulness of the various statements on a scale of 1 to 5 (with 5 as the best). The following results were obtained for the various statements about activities in the group:

- Possible benefits:
  - More comfortable on the team then alone: 3.6;
  - Easier, faster troubleshooting: 4.0;
  - Easier and faster information retrieval: 3.5;
  - Higher performance: 3.8;
  - Values collective knowledge more than individually acquired knowledge: 3.0;
  - The team is more active than working alone: 3.4.

Based on all of this, teamwork is preferred by respondents because of faster information acquisition and problem-solving as well as higher performance.

Examination of the willingness to engage in group and individual activities yielded an interesting result. It is hardly easier to get respondents to work if they can collaborate (3.3) than if they have to work individually (3.1). Since there is a very slight difference between the values, the question is why the previously stated (and more or less clearly evident) positive attributes did not add value to the motivation for cooperation.

- Possible disadvantages:
    - It is important not to adapt to others: 2.9;
    - You can get deeper if you are alone: 3.6;
    - Knowledge gained through individual activity is deeper: 3.4;
    - It is more favored to work with machines rather than people: 2.9;
    - They like organizing themselves and their activities: 3.9;
    - The advantage of individual work is that it is free of conflict: 3.6;
    - Work is more productive if you do not have to wait for others or to argue with others: 3.6.

Thus, we can conclude that the need for independence and the avoidance of conflicts justify the need for an individual form of work solution.

It is clear from the students' answers that we, as educators, need to be open to innovative, disruptive technologies in order to keep up with their needs by delivering knowledge in a format that is favored by the Y and Z generations. And of course, they basically like to collaborate, to co-operate with each other, but that does not mean that this is the only "magic weapon" that is perfect in every situation. The right form of work should be well chosen in the given situation, subject and actors.

Conclusions

There are many factors that influence learning success. It depends on personal competences, the nature of the topic to be addressed, the learning environment, the available equipment, the applicable methodological repertoire and so on. The successful output is best assured when the priority between the influencing factors is designed according to the goal to be achieved. Rising above the traditional approach opens the door to a wide range of possibilities, both in a tangible real-world environment and in the virtual space, but can be fully utilized with healthy self-knowledge and appropriate prior knowledge.

Characteristics of today's learning society, such as the need for experiential learning that provides autonomy and flexibility, digital communication, openness to virtuality, the availability of instant information and constant online connectivity, the preference for small units that are easy to process and social activities, cooperation, and preference for collaboration also direct the individual learning process towards community space, community wealth, community experience, and collective knowledge. [33] [34] Students prefer subjects where they can work in teams, that is to say, rather than autocratic control, they are in an equal decision making position, but responsibility is shared. Beyond that; however, they get the autonomy they desire, as they individually perform the tasks that are appropriate to their role and that are most appropriate to their competencies. [35]

Taking into account students' different personalities, as a member of a team, whether extroverted or introverted, the individual is capable of self-realization and development. Extroverted energy derives from social interactions in a cooperative, collaborative, supportive environment. Compared to the opinions of others, team spirit also contributes to the efficiency of their work in solving problems that they are capable of. The distribution of responsibility can be liberating, so the fear of possible failure is minimized, making the individual much more impulsive in problem-solving. [36]

Individual work in roles that match the personality traits within the team favors introverted personalities in depth. As they work on assignments that match their competencies, students can follow their own schedules to achieve the goal set by the team. Individual work within a team has the potential for productive work, which leads to the completion of successful subtask with its own time and energy, thereby creating a feeling of happiness for the individual. Not having to adapt to others can increase the efficiency of the work, but is also aware of the fact that you can count on the help of team members when they encounter a problem or a decision situation that gives their output a sense of uncertainty. [37]

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The Correlations between Health Behaviors and the Use of Health-Preserving Mobile Applications in Young Adults

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Abstract: Individuals' lifestyles manifest themselves in daily activities that can have effects that are a health-preserving, preventive or risk-enhancing, in terms of health. Some of them are simple everyday activities, as eating, exercising or smoking, which are closely related to health without being specifically viewed as health-related behaviours. In the case of university-age young people, a similar activity that affects health is the use of smart devices. Like any other factor, this can also have both positive and negative impacts on health.

In this study, we looked at the health status of university-age young people, as well as their habits in using smart applications. The results have shown that the health of university students studying in Serbia and Hungary is satisfactory in several respects. In addition, several correlations can be seen between their general well-being, their exercise and eating habits, as well as their use of smart devices, applications, more specifically, applications aimed at health-care.

Keywords: smart devices; health-preserving applications; health behaviours

1 Introduction - Health-Care

1.1 The Concept of Health-Care and the Influence of Lifestyle Factors on Health-Care

In a health psychological approach, health-care refers to personal attributes of an individual for maintaining, restoring health, and having significant social and community, social and cultural determinants [7].

There are two types of health behavior [5]. The first is positive health behavior, which includes activities contributing to maintaining or restoring health. The second type is health-risk behavior. These are activities that, when practiced, increase the chance of developing a disease or injury [7]. Lifestyle factors such as nutrition, physical exercise habits or smoking, drugs and alcohol have a significant impact on a person's health.

Nowadays, one of the main goals of researches related to health psychology is to identify and test in practice those factors, theoretical models and programs that may be the most effective ways of changing health behavior [1].

Regular physical activity is one of the most effective protective factors against the most common chronic diseases, cardiovascular disease. In addition, the nutrition of an individual has a significant impact on health, too.

In the last decade, parallel to studies on lifestyle factors, research into the impact of psychosocial factors on health status has come into view. These mental health-related factors primarily influence mental health, but also physical health. Psycho-social risk factors include social inequalities, unemployment, social deprivation, work, and family stress, and depression. These have a significant impact on the morbidity and mortality rates of the group [3].

1.2 Relationships between the Online Educational Environment and Health Behaviours

There are many places for realizing health promotion strategies, the most important of which is the place where education is provided, i.e., the online learning environment provided by educational institutions and ICTs [8].

The key aspect of developing good health behavior is relevant information. The appearance of smartphones has been one of the greatest steps in gathering information, accessing a variety of data and using common IT applications [4]. These tools are now an important aid in shaping young people's health behaviour [12].

Promising opportunities for online health-care are offered not only by the Internet, and social networks, but also more and more frequently by various mobile apps [6].

There are apps, which measure blood pressure or blood sugar, calculate how many steps one ought to take each day, or how much water one should drink. There are certain apps that monitor how long one's deep sleep phase is at night, others will warn the user to exercise regularly or limit their calorie intake.

2 The Correlations between Health-Care and the Use of Mobile Health Applications

2.1 Aim of Research

The spread of smartphones provides new forms of health communication and diverse opportunities for educating healthy lifestyles. Health-care applications can also be an important aid in shaping young people's health behaviours. The aim of our research is to investigate if health behaviours and the variables determining the general health status of students can be related to the frequency of using health-care mobile applications.

2.2 Research Hypotheses

H1: The health behavior of the majority of students (75% of the sample) is satisfactory.

H2: Students whose health status is satisfactory use health-care mobile applications less.

H3: The majority of students, who exercise frequently, use some kind of proven mobile application.

H4: Students with satisfactory eating habits use smartphone applications significantly more than those who, according to their own admission, are not eating properly or are not interested in a balanced diet.

2.3 Method

The study involved four higher educational institutions from Hungary and Serbia. The online survey was completed in January 2019. The questionnaire was distributed to students in two languages, either Hungarian or Serbian, depending

on the language of teaching at the specified institution. The questionnaire consisted of 5 sections. The first section examined the general (background) data of the students. The second to fourth sections asked students about their general health, sports, and nutrition habits. The fifth part of the questionnaire included questions related to the use of mobile devices and mobile health applications. The questionnaire survey was prepared online using the google form, which is available here:
https://docs.google.com/forms/d/16Vsaf7PUctnyC6whBJUw8dURm8TldmpK9cMRKQNk380/edit

2.4 Sample

Students from higher education institutions in Serbia and Hungary were included in the research. A total of 329 students participated in the survey.

Background data of the sample

(1) Gender: 40% of subjects were male (N = 130) and 60% female (N = 198).

(2) Institutions involved in the investigation:

The students of three Serbian (SRB) and one Hungarian (HU) institutions took part in the study. The distribution of students by institution is illustrated in Table 1.

Table 1
Institutions

		N	%
SRB	TFZR (Technical Faculty "Mihajlo Pupin")	166	50
	MTTK (Hungarian Language Teacher Training)	87	27
	VTŠ (Subotica Tech - College of Applied Sciences)	16	5
HU	BME (Budapest University Of Technology And Economics)	60	18
	all	329	100

Language of teaching

Among the students in the sample, there were students from Hungary whose language of instruction is Hungarian. Participants from Serbia included students whose language of education is either Hungarian or Serbian. The authors examined the differences in the results of students studying in each language of instruction.

Two categories were created based on the variables:

Students studying in their native language in their country: 69% (N = 228)

Students studying in a minority language in their country: 31% (N = 101).

Studies:

Teaching: 42% (N=139)

Computer Science: 29% (N=95)

Engineering: 26% (N=85)

Economics: 3% (N=10)

2.5 Results of the Research

2.5.1 Health Behaviors, General Well-Being

Students were asked about their general health using a five-level Likert scale. The average score on the scale: 4.09 points (standard deviation 0.72) out of a possible 5 points. On the scale, the score of 2,5 represents the neutral limit. Anything below represents students' negative attitude towards health, while anything above represents a positive attitude. The value obtained shows that the majority of students have a positive opinion of their health status. (see Figure 1)

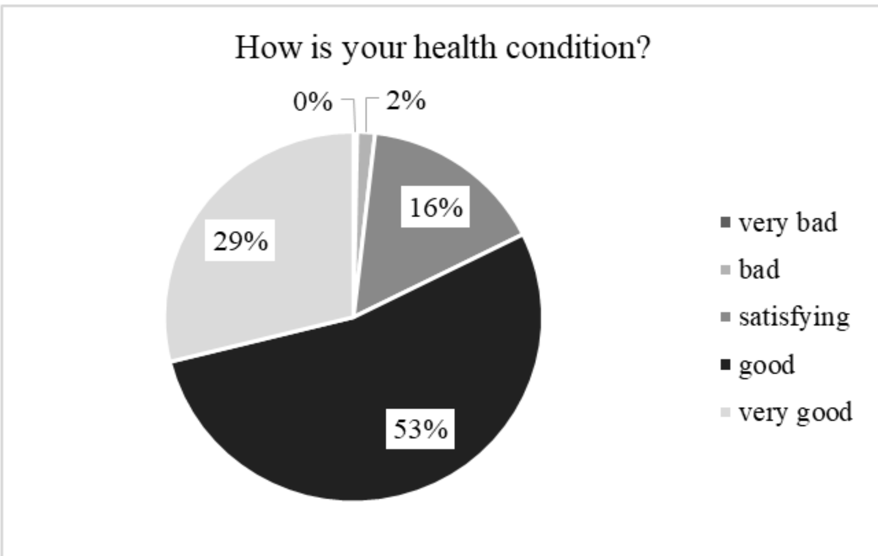

Figure 1

The general health of students

Of the surveyed students, 21% are suffering from some kind of chronic illness, while 79% of them claim they are completely healthy.

We asked the students about their available options, and what they can do in order to preserve their health. They could answer the question on a four-level Likert scale, where 1 means they can't do anything, and 4 means they can do very much. There was only one student who said they couldn't do anything to preserve their health. 15 students (5%) said they could only do a little. 178 students (54%) claimed they could do a lot, while 135 students (41%) claimed they could do very much in order to preserve their health.

A total of 18% of the surveyed students stated they were regular smokers, 10% occasionally and 72% were non-smokers.

The recorded results in regards to health behaviours support hypothesis H1. The surveyed students are in a good state of general well-being, the majority does not suffer from any chronic illnesses, and only a few of the surveyed students smoke, and according to their own admission, they can do much to preserve their health.

2.5.2 Exercise Habits

Students were asked about their exercise habits using a five-level Likert scale. Based on the results, 35% of students exercise several times a week, 11% admitted to not engaging in any physical activity at all, while the others exercised in different frequencies. The majority of students (79%) do not have a personalized training plan, and only 11% are professional athletes.

The majority of the surveyed, 46% exercise in order to stay in shape. 34% of the students exercise because they enjoy the physical activity. While a lot less, 16% in total, only exercise because they wish to lose weight. Only 4% of them exercise because it is either their profession or they do it competitively.

While the majority of the surveyed students use walking as their exercise. Cycling, jogging, and bodybuilding are also common forms of exercise among them. However, more students cited swimming, football, and aerobics as their favorite form of exercise. (see Figure 2)

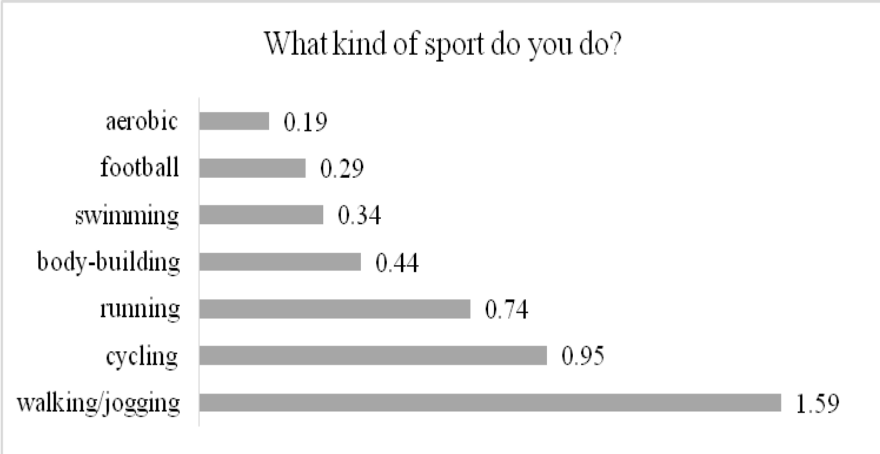

Figure 2
The general health of students

2.5.3 Eating Habits

Body mass index (BMI) is widely used to determine healthy body weight, overweight or leanness. BMI is a statistical measure calculated by dividing body weight in kilograms by the square of height in meters [7].

For 60% of the students in the study, the BMI index averaged 23.9, which means normal weight. 5% of the students were below normal weight, and 27% were overweight. A total of 20 students were Class I, 5 students were Class II, and one student was Class III of obesity (Table 2). The table is based on the levels of the BMI scale used by the World Health Organization [10] [11], where the body mass index values are ranked on a 6-level scale [9] (see Table 2).

Table 2
Students' body weight based on BMI scale values

BMI (kg/m²)	**N**	**%**
< 18,5: Underweight	17	5
18.5–24.9: Normal	197	60
25.0–29.9: Overweight	89	27
30.0–34.9: Obese Class I	20	6
35.0–39.9: Obese Class II	5	2
40 > Obese Class III (Very severely obese)	1	1

The results of students studying in Hungary and Serbia show differences in BMI, nutrition and the number of used mobile apps. The average BMI index for students studying in Hungary is 25.3, which belongs to the overweight category. In contrast, students studying in Serbia have a significantly lower BMI index ($t = 2.83$ $p = 0.005$). This group presented an average of 23.6 BMI, which belongs to the normal weight category.

The majority of the students, 37%, felt that their nutrition was unbalanced. 28% are not concerned about the issue, or do not care. Only 35% of the respondents stated that their nutrition was balanced. Regarding nutrition, Hungarian students considered their own nutrition habits much unhealthier than Serbian students ($t = -3.23$ $p = 0.001$).

Regarding the form of food, many of the respondents prefer meat, fresh fruits and vegetables, and dairy products to sweets, snacks, fruit juices or energy drinks.

The received results proved hypothesis H1, the health-care behavior of the interviewed students is satisfactory in regard to general health. The general well-being of the surveyed students is satisfactory, most of them don't suffer from any chronic illnesses, only a few of the surveyed are smokers, and according to their own admission, they can do very much in order to preserve their health. The majority of the students exercise on a regular basis, although only a few of them do it in a competitive manner. The results indicate that their health behavior is satisfactory in terms of exercise habits as well. Most of the students' BMI index falls into the normal category. Despite the fact that the majority of students admit that their diet is unbalanced, the respondents prefer healthy foods over unhealthy ones.

2.5.4 Results Related to the Use of Smartphones and Health-Care Applications

Most of the surveyed students use some kind of smart device, most of them (68%) use a smartphone with an Android operational system (Figure 3).

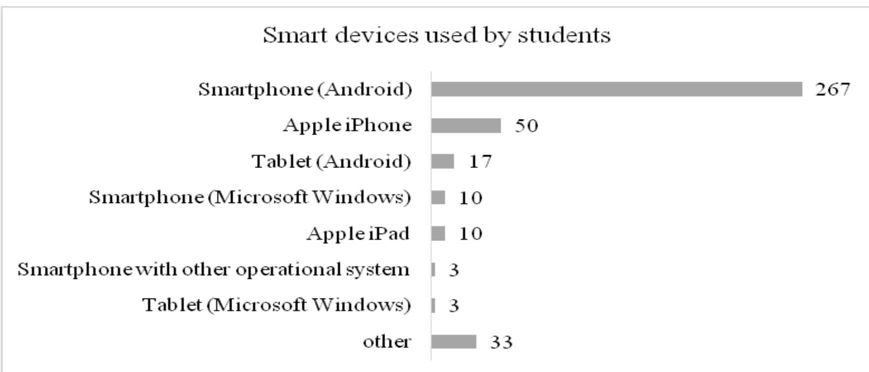

Figure 3

The most commonly used smart devices

Most of the students (39%) use between 6 and 10 apps on their smart devices. 23% use between 11-20 and 13% between 21-40. 4% of the respondents regularly use more than 40 applications, and 21% use 5 or fewer applications (see Table 3).

Table 3
Number of used smart applications

number of installed applications	N	%
5 or less	68	21
6-10	127	39
11-20	77	23
21-40	44	13
more than 40	13	4

The results of the two-sample t-test show no gender difference in health awareness. There are no differences between the two genders in the use of health-care applications. The only difference detected was in the number of used mobile applications. Men use significantly more applications than women ($t = 2.93$ $p = 0.004$).

67% of the surveyed students use some kind of health-care application. The most frequently used applications are the Cycle Calendar and other fitness and health applications. Also, often used applications are Huawei/Samsung Health, Pedometer, Fitness, Yazio, Health, Calorie Base, Endomondo (see Figure 4). Concerning the number of mobile applications, students studying in Hungary use significantly more applications than students studying in Serbia ($t = 3.97$ $p = 0.001$). Students in the economics study programs use significantly more applications than students in the other three programs (teacher-training, IT, engineering) ($F = 6.14$ $p = 0.001$).

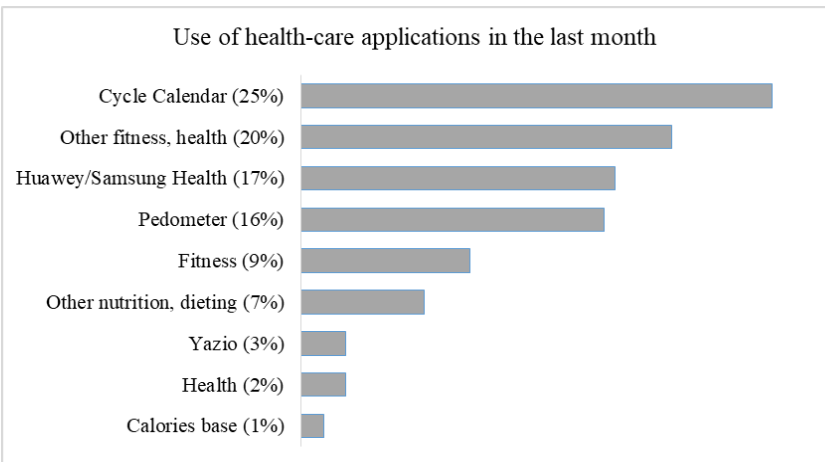

Figure 4
Health-care applications used by students

We examined whether students in good health (those who fall into the groups of satisfactory, good or very good) use any more health-preserving applications than those who have an unsatisfactory health status. We found that those in good health use less health-preserving applications (t=-2,75 p=0,006). Based on the results we can conclude that the use of a few specifically selected, proven applications that have a real positive effect on health are much more expedient than the effects of randomly downloaded, infrequently used applications.

From the students who work out regularly (once or multiple times a week, or daily) 61% use a smart application, of which 39% use apps related to fitness, exercise or physical activity. Here, as well, the number of those who do use such applications, but only less than 5, were significantly higher (t=-3,02 p=0,01).

2.5.5 The Correlations between a Healthy Lifestyle and the Use of Health-Preserving Applications

We examined whether students in good health (those who fall into the groups of satisfactory, good or very good) use any more health-preserving applications than those who have an unsatisfactory health status. Pearson's correlation study has shown that there is an inverse correlation between general health and the number of health care applications used (r=-0,14 p=0,009). The correlations are supported by the two-sample t-test as well. Based on the results, we found that students in good health use less health-preserving applications (t=-2,75 p=0,006). These values support hypothesis H2, meaning that the use of a few specifically selected, proven applications that have a real positive effect on health is much more expedient than the effects of randomly downloaded, infrequently used applications.

From the students who work out regularly (once or multiple times a week, or daily) 61% use a smart application, of which 39% use apps related to fitness, exercise or physical activity. The frequency of exercise shows a significant correlation with the use of health-preserving applications (r=0,11 p=0,04). According to the two-sample t-test, the number of those who do use such applications, but only less than 5, were significantly higher (t=-3,02 p=0,01). These results confirm hypothesis H3.

The studies have shown that students who have a balanced diet use a lot more health-preserving applications (t=2,14 p=0,04), than those who, according to their own admission, are not eating properly or are not interested in a balanced diet.

The above results prove our statement in hypothesis H2. Students in satisfactory health, who exercise regularly and have satisfactory eating habits use significantly more health-preserving smartphone applications than students with health problems.

3 Summary of Research Results

The examination of the students in the sample has revealed that the health behavior of students is satisfactory, even according to their own admission. There are only a few who suffer from a chronic illness or smoke on a regular basis. They are aware of their available options, which can help them in preserving their health, and the majority does take advantage of these options. The results have shown that the majority of students do partake in physical exercise, although with varying regularities. Most of them take walks, but a wide range of other forms of exercise were also noted during the survey. In terms of their body mass index, the participating students fall into the normal body weight category and have satisfactory eating habits.

The majority of students participating in the survey do use a smart device and mobile applications. We were able to find multiple correlations between the use of such applications and the health behaviours of students. Those who consider themselves less healthy download more of these applications, while students with satisfactory health statuses still use health-preserving applications, but only a limited number of them, and in a more conscious manner. Young people who exercise regularly also have their proven applications, which they use often, while students with balanced diets also demonstrate the use of such health-preserving applications. There have been similar studies in the past in the same topic that have confirmed our own research [13].

Conclusion

The most important goal of comprehensive health promotion is that everyone from the youngest to the oldest age should take part in systematic health promotion activities that effectively contribute to full physical and mental well-being and health. Any widely-used development activity must take advantage of the achievements and tools of ICT. The modern ICT based tools applicable in the field of VR and AR [14]-[16], gamification or cooperative techniques [17]-[19] and other field of Cognitive Infocommunications [20]-[25].

The use of smart devices in health promotion does not hamper health-conscious behavior but supports and develops the user's goal of pursuing a healthy lifestyle.

The use of health-related applications facilitates the acquisition of information, can trigger changes in health attitudes, reveal new opportunities, and aid the users on their path towards a healthy lifestyle.

The results of our research support the assumption that the use of mobile applications can help university students to develop and maintain a healthy lifestyle, regular physical activity, and healthy nutrition habits. This field requires continued research: as this work has shown, the views of university students must be taken into account when developing mobile applications and even in designing comprehensive health promotion programs. We are planning to expand the scope of the survey in the future.

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Educational Tool for Testing Emotion Recognition Abilities in Adolescents

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Abstract: Emotion recognition represents an important predictor for the development of social interactions. Previous studies have shown that the ability to recognize emotions, the speed, and accuracy, with which individuals process emotions, is an ability that develops with age, starting from early childhood. Children with autism spectrum disorder (ASD) show reduced attention to faces and they have difficulties in identifying emotions. Our goal was to investigate the effectiveness of a technology-based educational tool for assessing emotion recognition skills in individuals with ASD and typical developing children.51 children aged between 12 and 14 years were enrolled in our study, out of which 11 have a diagnosis of ASD. Our results reveal that adolescents perceive emotions differently depending on the type of stimuli that we use and on their ages.

Keywords: emotion recognition; educational tool; adolescents; autism spectrum disorder

1 Introduction

Socio-emotional development of adolescents is highly connected with initiating social interactions and maintaining friendships. The ability to recognize facial expressions is part of social cognition development, which includes the understanding of other's intentions [1-2]. Labeling basic emotions, such as: happiness, sadness, fear, and anger, is a task that preschoolers can do it easily; moreover, by the age of four years, they start recognizing more complex emotions [3]. There are a lot of variables that can influence the ability of emotion recognition, but recent studies suggest that the ability to recognize facial expressions can be related to the type of stimuli/tasks that are being used in the assessment process [4-5]. The ability to recognize emotions appears to be a continuous process, meaning that the performance of correctly identifying facial expressions improves from childhood to adulthood [6-7]. When it comes to atypical development the ability to recognize emotion can be impaired and it can interfere with children's interpersonal connections and socializing. [8-9].

Autism spectrum disorder (ASD) is a neurodevelopmental condition that affects social interaction, communication, interests, and behavior. There are some studies showing that individuals with ASD have difficulties in accurately identifying emotions and interpreting socio-emotional cues [10-11]. According to recent studies, the ability to identify facial expressions is considered part of social communication skills and can predict adaptive social behavior [12].

While in typical developing children the capacity to distinguish between different types of emotions develops in their infancy [13-14] and children become more and better at this as they grow, in contrast, individuals with ASD demonstrate decreased interest and attention [15-17]. Therefore. one possible explanation for the facial expression recognition difficulties in children with ASD is the fact that their attention to faces, more exactly to eyes, is impaired [18-19]. Moreover, recent research revealed that children with ASD process faces gradually (i.e. piece by piece) rather than holistically [20-21]. Considering all the above research and also other important studies in this domain we may state that children with ASD experience deficits in facial emotion recognition [22-25]. However, there are a couple of studies that revealed interesting results in this domain, considering that children with ASD may have similar performances in identifying emotions as typically developing children [26-29].

These emotion recognition difficulties are important to be investigated because they can impact the social development of individuals with ASD and lead to social exclusion and can represent an obstacle in accessing and sustaining education [30-31]. Recent approaches suggest that the use of technology as educational instruments for evaluating and improving the emotional abilities of children with ASD may be particularly beneficial for addressing motivation and generalization issues. The rationale of using technological tools in the educational process of children with ASD is that these types of tools combine learning theory, motivational theory and game design to create a unique and exciting remediation ways which may be particularly beneficial to individuals with ASD [32]. Empirical evidence in education suggests that educational technology-based tools can foster enhanced motivation and facilitate the generalization of skills from the educational setting to different social contexts. However, findings from a number of interventions which have adopted a number of the game design principles have demonstrated success in improving this skill only to a limited degree [33]. Future research needs to be done in order to elucidate if this approach could be useful for children with ASD. Moreover, from our knowledge, there are no studies that propose the investigation of facial expression recognition from a developmental point of view including also a sample of individuals with ASD. Some recent reviews suggest that the performance in identifying emotions depends on the type of the assessment instrument, on the sample characteristics and if dynamic or static items are involved in the tasks used [34-35].

Based on the findings regarding the use of technological tools in the education process of children with ASD there was a series of computer-based interventions that were developed for this special population. The use of a screen can guide children with ASD to focus only on the relevant contents from the screen, helping them to ignore irrelevant data [36]. Considering the fact that children with ASD find social interactions challenging, mainly because are not predictable and intuitive, using a computer for providing the learning content instead of a teacher/therapist can make their job easier and more predictable [37]. Employing different types of technology-based tools for individuals with ASD may contribute to the development and practice of different abilities, which are necessary for social inclusion [38]. There are several programs that used different approaches in order to train the ability to recognize emotions, among them we mention: *Mind reading Program* [39]; *The transporters* [40, 41]and *Reading the Mind in Films* [42]. All these computer-based programs have tried to enrich the classical techniques of teaching emotions. Some of them used situation-based emotions illustrated in short films; others tried to gain attention by positioning the facial expressions on trains.

Although there are several limitations and unanswered questions in the domain of using technology-based instruments for children with ASD, such as to what extent they can generalize the information learned in a digitalized environment; these types of tools have a great potential of becoming standard educational programs. Therefore, is important to mention the advantages of using technological tools in the educational process of children with ASD. Correspondingly, users can remain motivated in the assessment task and intervention program because their interest can be controlled through personalized digital rewards; users can work at their level of understanding and these technological instruments do not require the use of social abilities that can be stressful for children with ASD [43-44].

1.1 Objective of the Current Study

In our study we propose to develop and test the effectiveness of a facial expression recognition instrument, which can be used both for typical developing individuals and for adolescents with ASDusing a technology-based paradigm. By including groups of children of different ages we also plan to approach the developmental aspect of emotion recognition process. Further, using different types of stimuli allows us to investigate if the ability to identify different emotions is dependent on the way the task is presented. The tasks used in our study ranged from full faces showing facial expression, to eyes part showing emotions to dynamic video stimuli that were presented in a tablet format. Therefore, our objective is to identify: a) if there are differences between the three types of the tests, with a better performance in the video phase compared to face and eye phases, b) if there are differences between the two groups investigated (typical developing children vs. children with ASD), c) if the ability of emotion recognition improves with age; and d. which type of emotion is better recognized in the two groups of participants.

1.2 Description of the Emotions Proposed to Investigate in our Study

For the development of our instrument, we have selected four emotions: happiness, sadness, anger and fear, which are known as basic emotional expressions and are recognized worldwide [45-48]. Every facial expression included in our study is easy to be reproduced and recognized by adults, mostly because they are able to identify the positions of facial muscles for each emotion. The elements that are involved in the production of each of the basic emotions are usually eyebrows, eyelids and lips [48]. Moreover, [49] each emotion has been associated with some action tendencies; some ideas that can be transmitted (communicated) through that emotion and some needs that can be expressed by using a type of expression or another (see Table 1).

Table 1

Description of action tendencies for the four basic emotions investigated in the study [49]

Emotion	Behavioral and action tendencies
Anger	Aggression (verbal or physical/ direct or indirect)
Fear	Avoiding threat / Seeking safety
Happiness	Persevere in the same action
Sadness	Withdrawal from enjoyable activities

2 Methodology

2.1 Participants

Before the implementation of the study the assessment protocol underwent an evaluation by the Ethics Committee from Babes-Bolyai University. All the participants' parents' were informed regarding the steps of the assessment protocol and each of them signed an informed consent through which they expressed their desire to participate at the study. Fifty-one children, aged 12-14 years, were enrolled in the study out of which 40 typical developing children and 11 children with ASD. Subjects from the typical developing group were recruited from Wesselenyi- Zalău Reformed High School Mass School. Children with ASD attend School for Inclusive Education in Simleul Silvaniei or Noro Center (a special daycare center which offers therapy services for children different developmental disorders). Children with ASD are aged 12-14 years and all have a confirmed diagnosis of ASD. Considering our hypothesis we have organized children in four different groups: one group of 12 years old children, one group of 13 years old children, one group of 14 years old children and one group of children with ASD (their ages varied from 12 to 14 years old).

2.2 Procedure

The setting for the experiments was a therapy room (about 20 m2) for the children with ASD, in which the children usually participated the therapeutic programs, so the children were familiar with the room and a regular classroom for the typically developing children. The therapist who performed the interaction is part of the research team of the Department of Special Education and she has experience in working with children with ASD. Children were presented in a tablet format with 12 stimuli illustrating facial expressions of the four basic emotions (happiness, anger, fear, and sadness). Children had to respond to the question, “How is the child feeling?” (see Figure 1)

Figure 1
The experimental setting

2.3 Instruments

The test consisted in 12stimuli presented in a tablet format both for adolescents with ASD and for typical developing adolescents. The test had three phases, in each phase children were supposed to recognize the facial expressions. In the first two phases the children had to recognize the facial expressions from pictures showed on the tablet, the first 4 photos were illustrating faces with emotions and in the second phase the photos were illustrating eyes (see Figure 2). In order to make sure that the set of stimuli used are valid ones, we have used the stimuli developed in the Emotion and Development Branch in the National Institute of Mental Health (NIMH) Division of Intramural Research Programs. They have created Child Emotional Faces Picture Set (NIMH-ChEFS) which represent a collection of pictures illustrating adolescents that show different types of emotions.

For the third phase children had to recognize the emotions from a video, the video stimuli used were created especially for this study and illustrate the head and a small part of body images from an adolescent. In order to ensure the high quality of these videos, two specialists in clinical psychology have classified each stimuli. Afterwards we have used a basic validation procedure, in which the stimuli were presented to a sample of 30 students. The majority of them correctly identified the emotions, in this way we could be sure that the selected videos illustrate prototypes of the targeted emotions. The test was provided in a child-friendly format, it could be seen as attractive as a leisure activity as well as an educational tool.

Face phase

Eyes phase

Video phase

Figure 2

Examples of stimulus from each phase of the test

2.4 Results

We have used the non-parametric test (Friedman) for comparing the performance in the 3 phases of the tests (face, eyes and video) for each type of group (12, 13, 14 years old children and ASD children). The Friedman test represents an omnibus test, which is used to compare the results from two groups when the data is distributed differently than normal. This test is an alternative to performing the one-way ANOVA test. After the overall comparisons were performed in case of significant results Wilcoxon signed-rank test was used. By performing pairwise comparisons we could identify the conditions that yielded differences in performance that are statistically significant. The Wilcoxon signed-rank test is the nonparametric test equivalent to the dependent t-test.

For the 12 years old groupFriedman test showed significant differences between the three phases of the test, $Chi^2(2) = 8.34 p < .015$. Pairwise comparisons showed that eye test phase yielded lower scores than video test Z= -2.54, p = .011. No significant differences were found between the face and eyes phases of the tests or between face and video phases of the test p > .05. Wilcoxon tests were used to investigate these differences (see Table 2)

In the 13 and 14 years old group we didn't find any significant differences between the three phases of the test p > .05. (see Table 2)

In the ASD groupFriedman test showed significant differences between the three phases of the test, $Chi^2(2) = 9.17 p = .01$. We found similar results as in the 12 years old groups, meaning that children yielded better performance in the video test phase compared to eyes test Z= -2.45, p = .014.No significant differences were found between the face and eyes phases of the tests or between the face and video phases of the test p > .05. (see Table 2)

Analysis per emotion tested

In the typical developing groups sadness had the highest rates of recognition in video phase of the tests. Therefore, in the group of children aged 14, all children recognized the emotion (100%), it also had high rates of recognition in the group of children aged 13-83% and in the group of children aged 12-77%.

Table 2
Means and standard deviations for the three phases (face, eyes and video) for each group

	Face		Eyes		Video	
	M	SD	M	SD	M	SD
12 years old	1.88	1.16	1.22	1.09	2.88	1.26
13 years old	2.25	0.98	1.87	1.03	2.25	1.26
14 years old	2.85	1.06	2.42	1.27	2.28	0.75
ASD group	0.63	0.80	0.36	0.64	1.27	1.42

In the typically developing group, after sadness, happiness and anger were also well identified by children, with rates higher than 50% in the group of children aged 13 and 14 in almost all phases of the test. In the group of children aged 12 sadness was best recognized in the face phase (88%) and they had similar performances in the eyes and video phase (77%). The same group had a good performance in recognizing anger in both three phases (66%). In the typically developing group, fear was the least recognized emotion, in some cases (in the group of children aged 14) none of the participants identified correctly the emotion (see Figure 3,4 and 4).

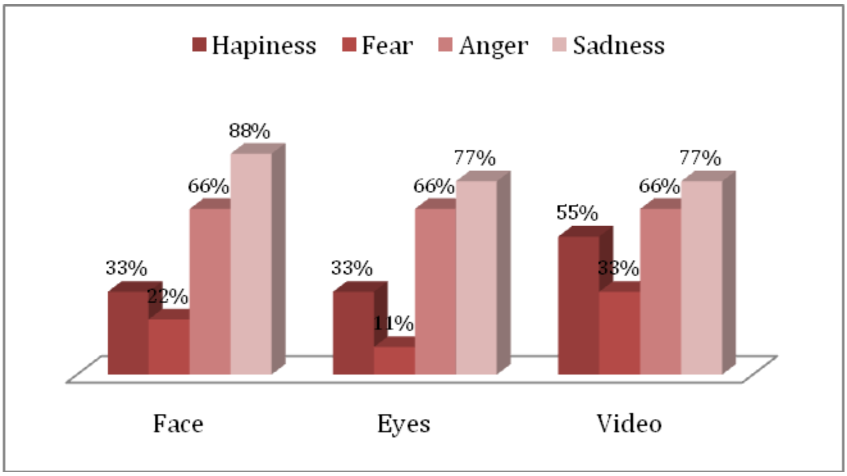

Figure 3
Performance of emotion recognition in the group of children aged 12 years - considering the emotion type

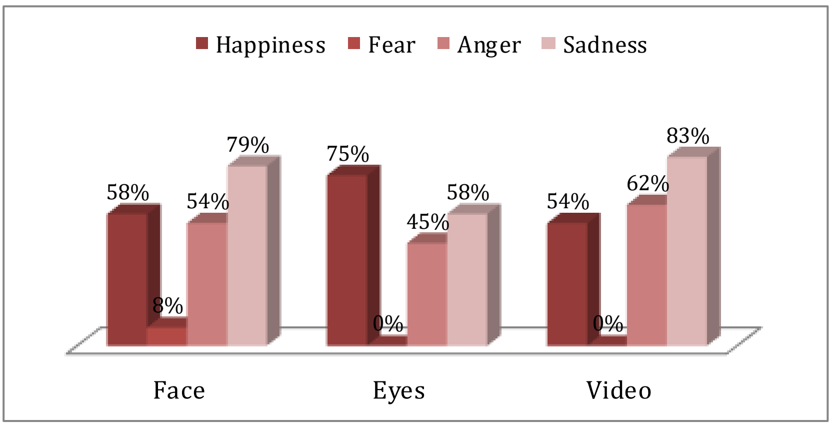

Figure 4
Performance of emotion recognition in the group of children aged 13 years - considering the emotion type

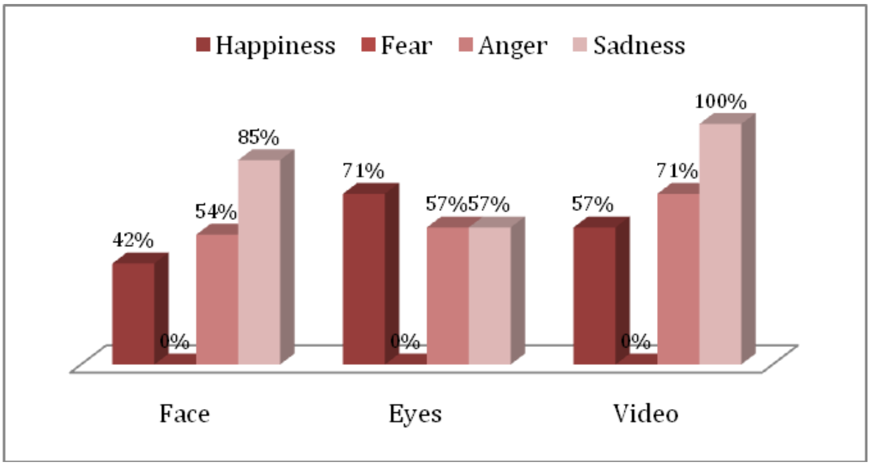

Figure 5
Performance of emotion recognition in the group of children aged 14 years - considering the emotion type

For children with ASD happiness was the easiest emotion to recognize in the face phase (36%) and in the video phase (63%). In the eyes phase, children with ASD had serious difficulties in identifying emotions, even happiness was identified with a very low rate (9%). In this phase, none of the children accurately identified fear and anger. Sadness was identified by children with ASD in the proportion of 27% in the video face, 18% in the eyes phase and 9% in the face phase. Similar to typical developing group, fear was the emotion most challenging for them to recognize. Also, they had some troubles identifying anger. Therefore, none of them recognized the fear in the eyes phase and it was correctly identified in the face phase only in a small percent 9% (see Figure 6).

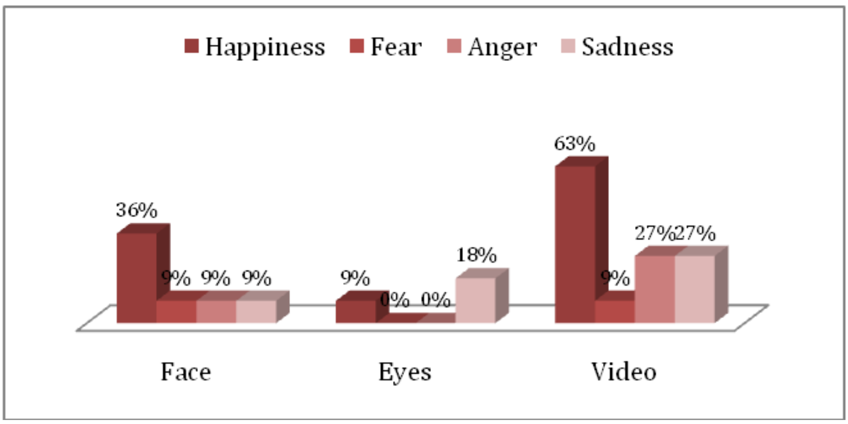

Figure 6
Performance of emotion recognition in the group of children with ASD - considering the emotion type

Regarding the performance of the adolescence with ASD in general (regardless of the emotion presented) the results showed a great variability (see Table 3). None of the children reached the highest score and four of them didn't succeed in recognizing any of the facial expressions. Some possible explanations of their weak performance could be the difficulties in the task understanding, their cognitive impairment and their severity level on the spectrum.

Table 3
Performance of emotion recognition in the group of children with ASD

	Video	Face	Eyes
Participant 1	3	1	2
Participant 2	4	2	1
Participant 3	3	0	1
Participant 4	1	2	0
Participant 5	1	0	0
Participant 6	0	0	0
Participant 7	0	0	0
Participant 8	0	0	0
Participant 9	1	1	0
Participant 10	1	1	0
Participant 11	0	0	0

3 Discussions

The competence of identifying facial expressions and using this information in a social environment represents an important step in the social inclusion [50-51]. Increased understanding of how typical and atypical children develop these abilities can generate effective assessment and intervention protocols which can enable individuals with ASD, and not only, to actively participate in the society. The findings of our study are in line with prior research [30] demonstrating that the type of stimuli that we use in order to identify emotions is important for the performance of children. Therefore, we have shown that the differences between the stimuli influence the way children with ASD recognized the emotions. They had a better performance in the video phase of the test compared to face phase and eyes phase of the test. We had similar findings for the 12 years old group of typically developing children. The fact that we didn't find statistical differences between the three phases of the test in the group of children aged 13 and 14 may be explained by the fact that as children grow they can better discriminate between different emotions regardless of the way in which they are presented to them.

Regarding the differences in the types of emotions that children with ASD compared to typically developing children recognized better in the video phase we must be cautious when interpreting the main finding because of the small sample size. Therefore, even if the children with ASD better-recognized happiness (63%) compared to sadness (27%), the emotion that was the best recognized in a typically developing group, we cannot generalize these conclusions and assume that these differences may be observed in the general population.

Conclusions

The main finding of our work indicates that the instrument developed (the test with three phases) has a good potential to evaluate the abilities of recognizing facial expressions. Children really enjoyed using the tables during the study and we believe that the reason is because the test was simple and engaging. The novelty of this study consisted in the manner in which the test was applied and the use of dynamic stimuli in order to increase the accuracy in measuring emotion recognition. As we have mentioned also in the introduction part, there is a need of evidence-based technology-based tools in order to provide appropriate interventions for developing facial expression recognition especially for individuals with ASD. Our research tries to contribute to the international literature in the domain by developing a user-friendly instrument that can be used for the assessment of emotion recognition. Further research should extend the area of emotions investigated, from basic to complex emotions in a cross-cultural study. By increasing the understanding of how typical and atypical populations perceive (e.g. ASD, ADHD), label, express and use the information about facial expression in their social interaction, by using effective emotion regulation strategies, we can further develop intervention programs for improving individuals' quality of life [52], [53], [54].

The results may help to find the development directions of modern ICT based teaching methodologies in the field of Virtual or Augmented Reality supported learning [55] [56] [57] cooperative or project-based teaching [58], [59], [60] and other possibilities related to Cognitive Infocommunications supported education [61], [62], [63] [64] [65].

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Mathability and Creative Problem Solving in the MaTech Math Competition

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Abstract: The Klebelsberg Center and the University of Dunaújváros, as a professional partner, organized the national MaTech math competition for the second time in 2019. The main goal of this competition is to develop creativity, creative problem solving, teamwork, and apply of digital knowledge in real mathematical problems when the mathematical capabilities co-evolving with human-ICT systems. This work presents an analysis identifying the characteristics of the mathematical knowledge and the relationship with the skill of creative presentation and performance.

Keywords: digital knowledge; creativity; teamwork; knowledge management

1 Introduction

For the second time in 2019, Klebelsberg Centre and the University of Dunaújváros, as a professional partner, organized the national MaTech math competition [1]. The competition is extraordinary in several aspects. First, participants have to cooperate in teamwork; the competition is conducted with the participation of groups of 3 members. Second, the use of digital tools is not prohibited; moreover, their professional use, in order to quickly solve the tasks, is inevitable. Third, such tasks need to be solved by the students in the competition, where a presentation accompanies the creative introduction of a task. During the years of 2018 & 2019, more than 500 individuals of three members teams were registered in the competition.

The mathematical problem solving and tool use, as well as, creative presentation, rely on multiple skills [2]. The first one is aimed at outstanding navigation in the world of information, the conscious application of information, whilst the second may be specified with specific skills of social advocacy. Accordingly, it is worth checking, what results have the participating teams achieved in math-specific, and what in presentation-specific tasks. Based on the results, we are looking for the answer on the question, in what extent does mathematical knowledge is accompanied by creative presentation, task introduction, and based on the results of them, what consequences may be stated, what features may be demonstrated primarily regarding mathematical knowledge and tasks requiring creative introduction and presentation.

The application of mathability inspires the students to contribute with cognitive sciences by assimilating new information, building new knowledge, develop problem-solving abilities and experience, using modern ICT devices [3]. In this way, the mathability, as a combination of artificial and natural cognitive capabilities, supports the education process to co-evolves with info-communication devices [4]-[9]. The perspectives of mathability inspired the main goals and methodology of the MaTech national competition.

In this article, the name MaTech1 refers to the competition in the school year 2017/2018, while MaTech2 refers to the competition in the school year 2018/2019.

1.1 MaTech - The Extraordinary Math Competition

The MaTech competition consists of three rounds; the evaluation of each round is made separately. The first and second round is conducted online, while the final in real-time. Teams of 3 members from the 10^{th} and the 11^{th} class of secondary schools may apply to the competition. The territorial distribution of teams registered to the competition is shown in Figure 1 (settlements delegating less than five teams are not indicated).

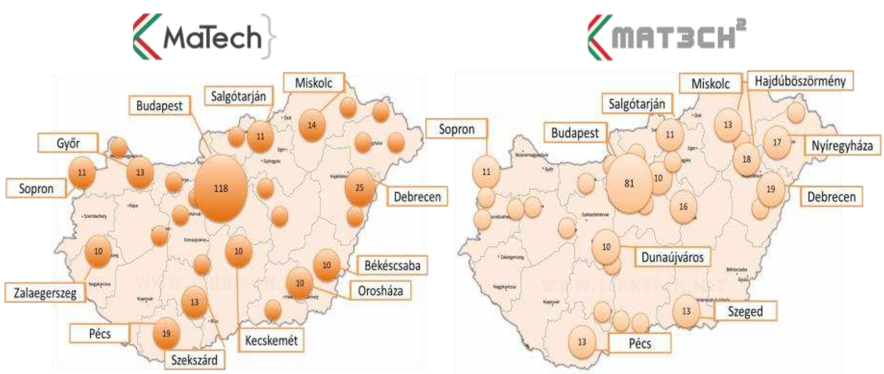


Figure 1

Territorial distribution of teams registered to the MaTech1 & MaTech2 competitions

The competition, beyond mathematical knowledge, focuses on creativity, digital tool use, problem-solving thinking and cooperation. The competition's individual nature is that it allows, moreover, requires, the use of smart tools, which is an absolute basic issue for today's secondary school students, meaning, that it has become an integral part, nowadays. For the successful participation in the competition, basic mathematical knowledge is obviously required, but the focus is on the improvement of thinking, experience-based learning and cooperation.

1.2 Focus on Digital Tool Use

The majority of the tasks of the MaTech competition, may be quickly and efficiently solved using digital tools; therefore, digital tool use is not prohibited at the competition, moreover, required. The use of digital tools is an opportunity, moreover, challenge for the team consisting of secondary school teachers, preparing the tasks. Among the tasks, the aim was the application of contents, features available online (image search, expressions, song parts, special contents), geographical searches had to be performed (GPS coordinates, Google Earth), reading of digital contents (QR code), even mathematical applications available online had to be used (e.g. Wolfram Alpha, GeoGebra), moreover, their application was necessary for effective and quick problem solving. In the final phase, two notebooks and one tablet were available for the teams to solve the tasks.

1.3 Creative Task Introduction, Presentation at the Final and in the Preliminary Tasks

The MaTech competition, in addition to the creative nature of the mathematical tasks, provides such challenges against the competing teams, where social competences, presentation skills, creative task introduction and presentation manifest themselves following each other. These creative tasks provide the opportunity to present certain factors of social advocacy in real life, and to benefit from both individual and team skills. In the preliminary task of round 2, and certain tasks of the final, those activities are highlighted, where it is not mathematical problem solving that plays the major role. The solution of this preliminary task of round 2 had not been mandatory yet but had been worth extra point. In the final, however, these tasks were also highlighted and were worth almost 40% in the total evaluation.

The creative task of MaTech 1's round 2, to be prepared in advance, was the design of the MaTech logo, as well as the preparation of a one-minute mini-film, where the teams had to demonstrate the solution of a geometric task, as creative as possible. Two ready MaTech logos are shown in Figure 2.

Figure 2
MaTech logo, as a preliminary task

The creative tasks of the MaTech1 Final were the preparation and demonstration of an infographic, and the introduction of the future of math education. In the Infographic task, the teams had to introduce themselves, their class, school and its environment live; however, all of these, through numbers, commented by quantities, data and correlations. In the task, it was up to the teams' imagination and creativity, how do they demonstrate it was using as innovative, creative, funny 'stats' and creative graphic elements as possible. A smart table was also available to illustrate the infographic to the teams.

One of the creative tasks of the MaTech2 Final, was again, the introduction, using an infographics, although, in the other creative task, the teams had to demonstrate their favorite math item not using a traditional presentation, but in some kind of genre (e.g. song, track, dance, epos, stand up, dispute, drama, poet letter, remonstrance). A presentation presented at the MaTech2 Final is shown in Figure 3 (on-site webcam streaming).

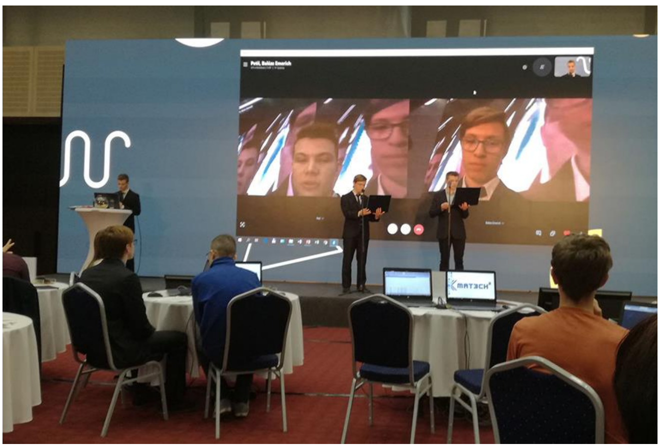


Figure 3
MaTech2 final creative task presentation

2 Creative Problem-Solving in Mathematics

Creativity is a key complex cognitive process examined by cognitive sciences [10]. Cognitive sciences examine creativity by evaluating our brain's cognitive responses on external stimuli, processing the collected information [11], also analyzing the role of memory [12, 13] and attention [14].

Creativity involves innate behavior and learned behavior. Creativity may be represented within particular levels. The Four C Model developed by Beghetto & Kaufmann [15] presents the potential levels of creativity within stages in life. 4 levels of creativity are identified:

- Big-C eminent creativity (like Picasso)
- Pro-C professional creativity
- Little-c everyday creativity
- Mini-c creativity involving learning

Creativity allows establishing a relationship between independent elements, to identify critical problems, respond on open questions on new ideas arising from curiosity. Creativity is represented in mathematics primarily in identifying new problems, working out of methods and tools of their solution, as well as the exploration of innovative methods serving as the resolution of unusual problems [16]. One method to establish original thinking situations is the presentation of open questions to the students, which requires a creative way of thinking and enables more than one answer [17].

Guilford [18] described creativity as problem-solving and concluded that the creative process has four stages:

- Recognition that a problem exists
- Production of a variety of relevant ideas
- Evaluation of the various possibilities
- Drawing of appropriate conclusions and solutions

Creativity and mathematical problem-solving correlate with each other, flexible thinking, which is one of the components of creativity, is one of the essential abilities in mathematical problem-solving. Based on Bishop's [19] experiences, two very different ways of thinking are required to solve mathematical problems: creative, intuitive, and analytic, logical way of thinking. According to Wachsmuth [20], problem-solving requires 'logical' and 'relaxation' mode in thinking.

For children, learning math is very important both regarding their later math studies and their general learning results in fields such as physics, science and technology [21], [22]. In several countries, creative mathematical problem-solving has not been integrated into the methodology of math education, but trained separately [23], [24]. Problem-solving is closely related to creativity in math too, primarily in those tasks, where a new solution had to be found on the new and the old problems [25]. So, in regards to mathematical knowledge, the revelation of new mathematical methods or ideas shall be highlighted, where a child's problem interpretation, illustration, creativity and reflection is in focus. Creativity develops, through the revelation of mathematical problems, both the development of problem-solving and a meaningful, logical way of thinking [26].

Technological development requires the application of mathematical knowledge and creative mathematical way of thinking in several fields. The report of the 2020 Science Group clearly highlights the available hardware and software capacity, which supports the solution of the world's complex problems, such as the planet's global warming or the spread of epidemics, although this might be a limiting factor in modelling such problems, where mathematics plays a vital role [27].

On the other hand, the everyday use of digital devices is usual among the young generation, that affects both the education system and the entire society. As a consequence of technological development, machines replace humans' role in more and more areas. Digital devices, however, become the determining tool of modern scientists, engineers and mathematicians, if they can properly use them. However, in math education, development of creative mathematical problem-solving, the credible use of digital tools has not been managed to (completely) integrate, in the fields of computerized algebra, modelling, simulation, statistics, data collection and 3D geometric [28].

As we can see above, by technological development, the spread of digital tools, the establishment of digital society, the ever-increasing scope of activities performed by the algorithms of machines, the relevance of creative mathematical problem-solving is becoming higher and higher. The mathability is also based on these findings and supports the cognitive processes to develop creative thinking and problem-solving abilities.

3 Research

The evaluation aimed to examine how a successful creative presentation accompanies mathematical knowledge. From the aspect of the evaluation, the sample consists of 10^{th} and 11^{th} class teams participating in the MaTech competition, which, due to the nationwide participation in regards to Hungary. The analyses presented in the research refer to teams participating in the competition. The evaluation is based on the performance analysis of teams entered to round 2 and the final, since round 1 relies only on tasks based on mathematical problem-solving, digital device use; thus the results achieved there are relevant only for either skill.

During the evaluation, among teams participating in Round 2, the results of those teams were evaluated, of which, had worked out the preliminary creative task too. All the 12 teams participated in the Final tested themselves in both task types; thus, the results of the Final's 12 teams were evaluated. During the evaluation, depending on the achieved number of points, each team was divided into four groups, regarding both tasks requiring primarily mathematical knowledge and creative presentation. These groups are: 0-25%, 25-50%, 50-75% and 75-100%, respectively, depending on the result. The evaluation of the teams' results was made using prevalence analysis and statistical methods.

4 Results and Conclusions

Teams also solving the preliminary tasks of MaTech1 competition's Round 2, their classification upon their results achieved in Round 2 in the mathematical tasks and the preliminary creative tasks are shown in Figure 4. The summary of results achieved in the mathematical tasks and preliminary creative tasks is shown in Figure 5.

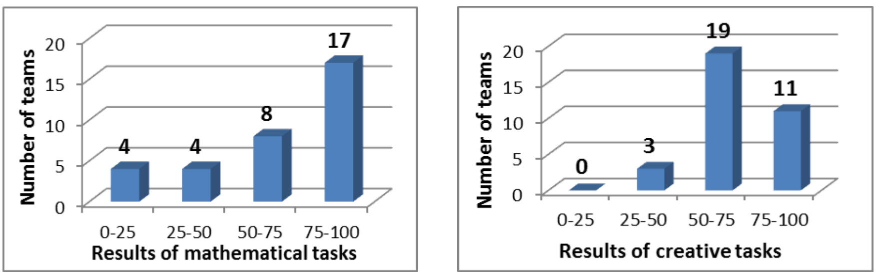
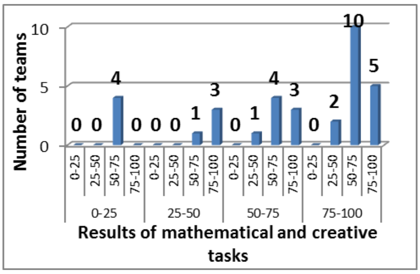


Figure 4

Number of teams participated to MaTech1, Round 2 according to their results achieved (horizontal: 0-25%, 25-50%, 50-75% and 75-100% depending on the results of Round 2)



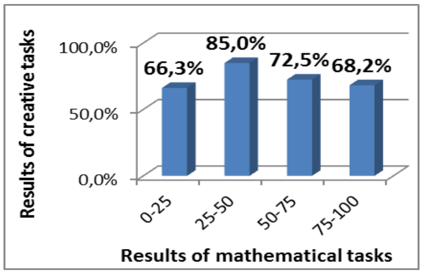


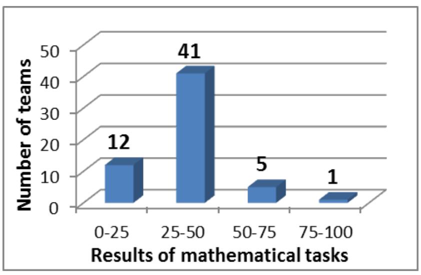
Figure 5

Comparison of results achieved in mathematical and creative tasks by teams participated to MaTech1, Round 2

(horizontal: 0-25%, 25-50%, 50-75% and 75-100% depending on the mathematical results of Round 2 and its distribution according to the results of the creative tasks)

It is clearly demonstrated by Matech1, Round 2, that the creative preliminary task was mostly made by teams achieving higher points at mathematical tasks. During the evaluation of creative tasks, the tasks of most teams have reached 50-75%. The comparison of mathematical and creative tasks shows that irrespective of the result achieved at the mathematical tasks, the average evaluation of the creative tasks were almost the same, in the range between 66-85%, and was the highest at teams achieving lower, 25-50% results at mathematical tasks.

Similar results of MaTech2, Round 2 are summarized in Figures 6 and 7.



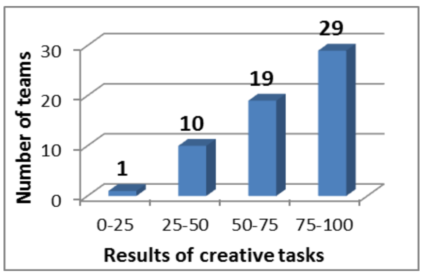
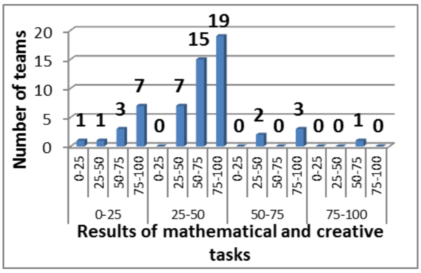


Figure 6

Number of teams participated to MaTech2 Round 2 according to their results achieved

(horizontal: 0-25%, 25-50%, 50-75% and 75-100% depending on the results of Round 2)



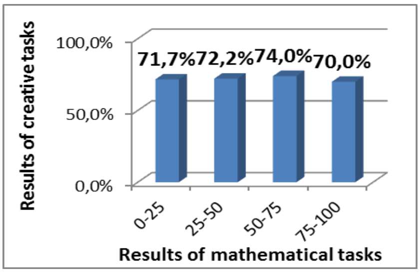


Figure 7

Comparison of results achieved in mathematical and creative tasks by teams participated to MaTech2, Round 2

(horizontal: 0-25%, 25-50%, 50-75% and 75-100% depending on the mathematical results of Round 2 and its distribution according to the results of the creative tasks)

It was clearly shown by Matech2 Round 2, that points achieved at mathematical tasks were lower; most teams were categorized into the 25-50% range. However, during the evaluation of creative tasks, the results of most teams were evaluated to 75-100%, indicating that teams are more and more prepared in this field too.

The comparison of mathematical and creative tasks indicates that irrespective of the results achieved at mathematical tasks, the average evaluation of the creative tasks were almost the same, within the 70-74% range, so practically there were no outstanding results in this grouping.

The comparison of the results of Round 2 of both MaTech1 and MaTech2 indicates that the mathematical tasks of MaTech2 proved to be more difficult for the teams, although they had more success in creative tasks. In both years, it is clear that results achieved at mathematical and creative tasks do not correlate, meaning that the evaluation of creative tasks is irrespective of the results achieved at mathematical tasks.

In case of the MaTech finals, the evaluation drafted above may also be performed. In the finals of both MaTech1 and MaTech2, the most successful 12 teams were participating. The evaluation of MaTech1

Final with similar aspects as above is summarized in Figure 8 and 9.

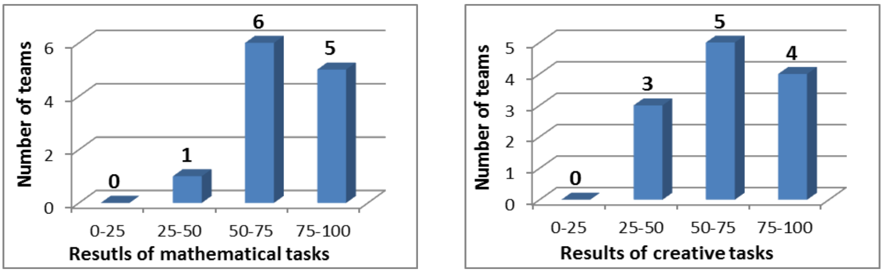


Figure 8

Number of teams participated to MaTech1 Final according to their results achieved

(horizontal: 0-25%, 25-50%, 50-75% and 75-100% depending on the results of Final)

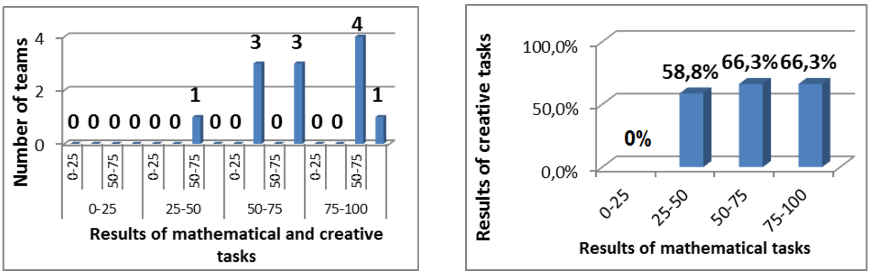


Figure 9

Comparison of results achieved in mathematical and creative tasks by teams participated to MaTech1 Final

(horizontal: 0-25%, 25-50%, 50-75% and 75-100% depending on the mathematical results of Final and its distribution according to the results of the creative tasks)

In the case of MaTech2 Final, the results of the evaluation are shown in Figure 10 and 11.

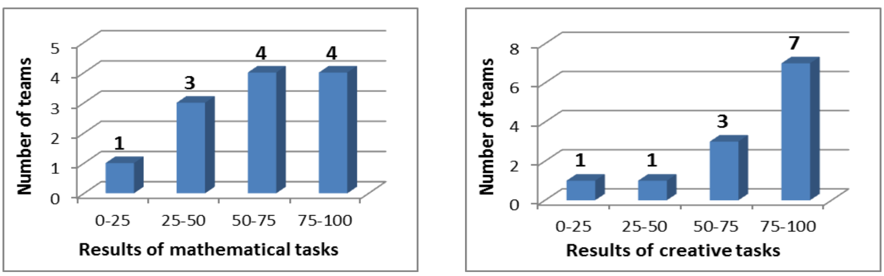


Figure 10

Number of teams participated to MaTech2 Final according to their results achieved

(horizontal: 0-25%, 25-50%, 50-75% and 75-100% depending on the results of Final)

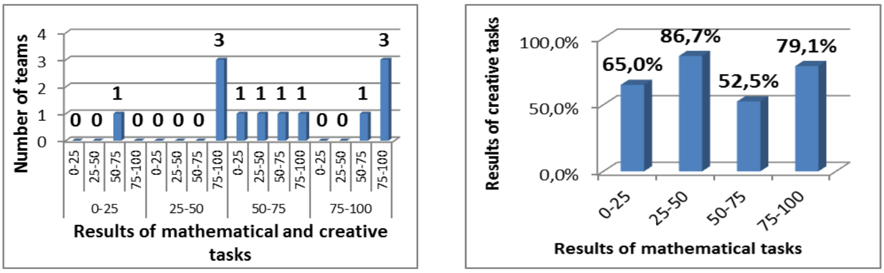


Figure 11

Comparison of results achieved in mathematical and creative tasks by teams participated to MaTech2 Final

(horizontal: 0-25%, 25-50%, 50-75% and 75-100% depending on the mathematical results of Final and its distribution according to the results of the creative tasks)

The comparison of MaTech1 and MaTech2 finals indicate that since the solutions of the mathematical tasks of MaTech2 were slightly less successful for the teams, an improvement is detected at creative tasks, 7 teams achieved results varying between 75 and 100%. Similarly, to the results of Round 2, the Final also demonstrated that results achieved on mathematical and creative tasks do not correlate in both years; in case of MaTech1 Final, the results achieved at creative tasks appear virtually irrespective of the results achieved at mathematical tasks that vary between 59% and 66%. In case of the MaTech2 Final, primarily compared to the results achieved at mathematical tasks, the evaluation of creative tasks varied between 52% and 87%; however, there is no correlation in the results, meaning that the evaluation of creative tasks is irrespective of the results achieved at mathematical tasks.

It is clear that the success of teams in tasks based on primarily mathematical knowledge does not correlate with tasks requiring a creative presentation, they show no correlation on the level of the individual skills.

5 Summary

The consequences of the evaluation of the competition results, indicates that, in the MaTech competition, results achieved at tasks requiring primarily mathematical knowledge, do not correlate with the success shown in tasks requiring a creative presentation. This finding indicates that in addition to lexical knowledge, the improvement of skills requiring creative presentation should also be taken into consideration. However, it is quite promising, that compared to MaTech1, there were better results within the solutions of the creative tasks of MaTech2 both regarding Round 2 and the Final. Skills requiring creative presentation have outstanding relevance in social advocacy; therefore, it is important to emphasize these competencies in the course of the education of the generations grounding within our future information based society. In the MaTech competition, these competencies also play a significant role in providing a unique feature to the competition, by focusing on digital competences. The ICT and a special topic, in this field, Cognitive Info-communication has the ability to emphasize the competencies of the new generation, through the power of gamification, cooperation, project based learning [29]-[32], cognitive ICT [33]-[37] or virtual spaces for improving attention and interest [38]-[42] and the extension of memory [43].

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Advanced Assistive Technologies for Elderly People: A Psychological Perspective on Seniors' Needs and Preferences (part A)

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Abstract: This paper provides an overview of the literature concerning Seniors' psychological perspective in exploiting assistive robots and the embodied conversational agents. The main theoretical models devoted to assess user's technology acceptance are briefly reviewed along with a description of the main factors empirically found to be positively/negatively associated with Seniors' acceptance level. Special attention is reserved to barriers generated by Seniors' representations of social assistive technologies, such as, a stigma or threat to their autonomy, infantilization, privacy interferences, fear of dehumanization and isolation.

Keywords: older user; assistive technology; robot; virtual agent; acceptance; preferences

1 Introduction

According to the United Nations, the number of people ages 65 and older will reach 2.1 billion by 2050 [1]. Luckily progress made in medicine and health care will help keep these Seniors healthy and in good shape mentally, even though physiological declines, such as, vision impairment, short-term memory problems and fine-motor deficits remain unavoidable. Depending on personal tendencies to react positively or negatively to life events and the severity of such impairments, Seniors may react by isolating themselves and limiting relationships with friends and relatives. However, social isolation is associated with reduced well-being and depression [2, 3] and increased mortality [4]. Interventions are needed to prevent these negative consequences and social isolation itself.

One possibility consists of exploiting intelligent and socially believable ICT (Information Communication Technology) interfaces that support Seniors in living autonomously, simplifying their management of daily tasks and lightening workloads for caregivers. According to Shepherd [5]: "*The Digital Era is characterized by technology which increases the speed and breadth of knowledge turnover .... [and] ... has changed the way we live and work and ... healthcare relationship.*" (pp. 1-3). Therefore, the development of the Digital Era implies that it's possible to use technology such as robots, and virtual agents, to help those who require assistance for daily life activities.

However, little is known about Seniors' interests in and willingness to interact with advanced assistive technologies in order to meet their needs. There is a general agreement that the successful incorporation of assistive social technologies in everyday life depends mainly on how the users perceive and accept them [6]. Robots and virtual agents may have to be adapted to meet users' specific needs and even personalized according to his/her likes and dislikes [7].

This paper reviews the literature on advanced assistive technologies aiming to improve the lives of older people and increase their well-being. The focus is on assistive robots and embodied conversational agents, in order to provide a full description and understanding of Seniors' psychological perspectives toward using such assistive technologies. The main theoretical models on user's technology acceptance, are reviewed and described and the main factors found to be positively or negatively associated with older users' acceptance are highlighted.

2 Understanding Seniors' Psychological Perspectives: Acceptance and Associated Factors

For people who are older, accepting new technology (i.e., the extent they are willing to incorporate it into their lives) *"is an adaptive negotiation between the improvements provided by the offered resource and the struggles required to allocate it into their personal environment"* [8, p. 2] [9]. It is necessary to consider the functionalities offered, of course, but other aspects are also urgent to analyze: the emotions the device may arouse, the cognitive effort required for its effective use, the engagement it produces, and the associated costs of having it. The information system (IS) and information technology (IT) literature describe several technology-acceptance models, most of them conceptualized for adult users.

2.1 Main Acceptance Models

The existing acceptance models have been mostly based on theories in psychology and sociology, and despite differences in complexity and content, they were all employed with the goal of understanding, explaining and predicting factors influencing users' acceptance and willingness to use certain technologies [10, 11].

The **Technology Acceptance Model** (TAM) [12] was developed in order to describe and comprehend potential users' expectations regarding information technology. The TAM highlights two variables influencing acceptance: (i) perceived usefulness, defined as the degree to which an individual believes that using a particular system will enhance his/her performance and (ii) perceived ease of use, defined as the degree to which an individual believes that using a particular system will require little or no effort [12, 13]. According to this model, the degree of acceptance of a technological device is a directly connected to the efforts needed to use it for practical purposes and the individual gains derived from its use in facilitating the accomplishment of a given task. The TAM model has been applied to many different categories of technological devices and has collected strong empirical support [14, 15], thanks to its adaptability to a variety of domains.

However, TAM lacked several important psychological variables. To correct this, the model was extended as TAM2 in 2000 [14] with the addition of two theoretical constructs, namely social influence and cognitive instrumental processes, which affect the perceived utility of a technological device and the intention to use it. The social influence processes are conceptualized as subjective norms (i.e., the individual perception that friends and relatives think that the person should or should not adopt the behavior in question), willingness, and compliance with others' opinions (i.e., the extent to which users perceive that their adoption decision is made willingly and is not mandatory), image, and social influence (i.e., the individual perception that adopting an innovative tool is a way to enhance his or her social status) [14].

The cognitive instrumental processes are theorized starting from the assumption that people derive their judgments of perceived usefulness by considering a system's functional usefulness in relation to their needs to complete a particular task. In other words, people assess cognitively how important work goals are consequence of performing the work by using the system, and develop opinions regarding its perceived utility. In this context, four cognitive instrumental determinants are identified:

- Relevance for the task - Does the user perceive that the system in question applies to his/her task? To what degree does it apply?
- Level of quality - Does the system perform adequately to complete the identified task?

- Demonstrability - Are the system's results tangible?
- Perceived ease of use

Essentially the TAM2 model accounted of theoretical mechanisms by which subjective norm can influence intentions to use a given system indirectly through the user's perceived usefulness. In particular, the model considered effects of how the user's perception that a significant referent utilizes the system leads herself to use it and how this perception changes during her own experience. It was hypothesized that the effects of the social influence weakened [14].

The extent to which the system's social skills and physical appearance influence user's acceptance were, however, neglected both in TAM and TAM2. Indeed, the user's expectations of the social abilities and semblances of such robot/agent systems play a crucial role in their acceptance [10] and were considered the premise for developing further theoretical models to predict user acceptance.

The **Unified Theory of Acceptance and Use of Technology** (UTAUT) [15] was formulated as the result of a review and synthesis of eight theories/models of technology use. These include Fishbein and Ajzen's theory of reasoned action [16]; Davis's technology acceptance model [12, 15]; the motivational model [17]; the theory of planned behavior [18]; a model that integrates the technology acceptance model and the theory of planned behavior [12, 18]; the model of personal computer utilization [19]; the innovation diffusion theory by Rogers et al. [20]; and the Bandura's social cognitive theory [21].

In the UTAUT model, four well-defined constructs are believed to have a significant role as direct determinants of user's acceptance and usage behavior of a given technology. These include user's expectation of performance (the degree to which the individual believes that using that particular system will result in gains in job performance); effort expectancy (the degree of system's easiness of use the individual perceives); social influence (the degree to which one perceives that her family members and friends believe she should use the system); facilitating conditions (the degree to which the potential user believes to be supported by organizational and technical infrastructures for using the system). In particular, the model posits that social influence, performance expectations, and effort expectations will determine one's behavioral intentions to utilize a technology, while behavioral intentions and facilitating conditions influence the degree of usage. Furthermore, UTAUT identified experience, willingness to use voluntarily, sex and age as moderate influencing factors in using a given technological system [15].

The UTAUT2 model extended UTAUT to a consumer context. To this aim, hedonic motivations (e.g., pleasure of using the technology), cost value (the cognitive trade-off between perceived benefits and expenses related to its use), and habits (the degree to which one engages in a behavior automatically thanks to learning) are integrated into the original model, as further determinants theorized to influence user's intentions and use behavior [11]. Similarly, individual differences (i.e., sex, age, user experience) have been confirmed as moderating the effects of these constructs on behavioral intentions and use of technology.

The **Almere Model** was proposed by Heerink and colleagues [22] and inspired by UTAUT. It addresses user acceptance of assistive technology, in particular the use of assistive "social" robots by older people. The model was developed starting with the assumption that traditional models of technology acceptance fail to consider variables related to social interaction with robots and were developed without considering older people as potential users [22, 23], as well as validated in workplace settings [24].

The Almere Model identified a combination of theoretical constructs as significant and potential determinants of the intent to utilize new technologies. These include anxiety, attitude toward using technology, facilitating conditions, social influences (from the UTAUT), and perceived usefulness and easiness of use (from the TAM). To these, the Almere Model added the constructs of perceived enjoyment, perceived sociability, and social presence (considered worth social robots), in addition to perceived adaptability, which is appropriate to account for when older people are involved [25]. In particular, perceived adaptability turned out to be specifically applicable to vulnerable people such as elders since they want a system to help them only when they need and is designed to adapt to their changing needs.

An assessment of the Almere Model showed that "perceived usefulness" and "attitude" are the system features that most significantly affect Seniors' intentions to use a robot. Age, sex, voluntariness, educational level and computer experience proved to be moderating factors in determining their acceptance [22, 26].

The **Technology-to-Performance Chain Model** (TPC) [27] affirms that the adoption of technology is a consequence of its specific utility and the ability/capability of the technology to align with the tasks it is expected to support (i.e., task–technology fit). The model stresses the importance of an effective match between a technology's function and tasks the user wants to perform for gaining a performance impact from information technology.

The TPC model considers as factors affecting technology adoption: task's characteristics (the activities the individual needs to perform to complete the task), features of the technology (the technological tools the individual uses to perform the task), individual characteristics (competence, motivation, and experience of the people using technologies in order to obtain assistance in performing tasks); task–technology fit (the level of assistance given by the technology in helping the individual to complete a set of tasks, namely the correspondence between task requirements, person's abilities, and technology's functionality); utilization (employing the technology to perform a task); and performance impact (individual's accomplishment of a set of tasks) [10].

Beliefs about the consequences of use, affect toward use, social norms, and habit-facilitating conditions are considered precursors of the technology utilization. The feedback the individual acquires when using technology and her performance are identified as additional aspects influencing a person's decision about using the system again [27].

The **Model of Acceptance of Technology in Households** (MATH) [28, 29], using the theory of planned behavior [18] as its theoretical framework, was developed to understand factors affecting the domestic adoption of a technology (e.g., buying and using a personal computer). The model identified three classes of constructs:

- Attitudinal beliefs (conceptualized as utilitarian outcomes) - These beliefs are related to personal utility, usefulness for children, and work-related usage, as well as to hedonic outcomes (how much enjoyment is derived, for using a personal computer) and social outcomes (involving any potential increase in prestige as a result of buying a personal computer for home use).
- Normative beliefs - Related to the influence that family members, friends, workplace colleagues and other sources, may have on the technology adoption.
- Control beliefs - Internal or external depending on whether they relate to personal abilities (such as, concerns about obsolescence due to the rapid technology advances, apprehension related to one's beliefs regarding the skills and knowledge needed to use a personal computer, perceived easiness of use) or environmental factors (such as decreasing prices inhibiting the adoption of personal computers).

Brown and Venkatesh [28] proposed a theoretical extension of the MATH model integrating as demographic characteristics age, marital status, and child's age, that can change throughout one's lifespan and are considered to play moderating roles in the adoption of a technology.

To predict long-term engagement with a social agent, of significant interest is the attempt of Bickmore et al. [30] to exploit concepts proposed in the **investment model of personal relationships** for understanding the main processes involved in the maintenance of a relationship with an agent. The investment model, which is supported by empirical evidence [31, 32] was developed to explain engagement and commitment to close relationships.

According to the investment model, dependence upon and long-term orientation toward a relationship increases as a consequence of specific factors such as higher satisfaction, lower perceived quality of available alternatives, and greater investment size.

In line with this theory, Bickmore et al. [30] argued that individuals feel committed to a social agent because (1) they feel satisfied since the relationship provides rewards and does not involve significant costs (the user perceives that there are advantages related to interacting with the agent, e.g., they receive entertainment and/or useful information); (2) they have invested important resources in the relationship (the user view the system as an investment), and (3) their beliefs to have few available alternatives to their relationships. These factors all contribute to the user's commitment to a long-term relationship with the agent as well as to increase the likelihood of using the system [30].

2.2 Main Factors Found to be Positively/Negatively Associated with Senior's Acceptance of Social Agents and Robots

Literature examining acceptance of robots and social agents by Seniors has empirically supported the roles of most of the factors identified by the above-mentioned acceptance models in influencing and moderating user acceptance.

However, beyond such formalized theoretical models, several further variables, often grouped by specific categorizations, were proposed as being associated with Seniors' acceptance.

De Graaf et al. [6] identified five main factors that may be considered to positively or negatively affect the elders' willingness to use and entrust a relationship with social agents and robots in the domestic sphere. **Utilitarian factors,** exemplified as accessibility and usability (the easier to use people perceive the device, the higher will be their level of acceptance), practical benefits (e.g., facilitating care delivery, enhancing personal safety in one's home, being a source for general information and health improvement), adaptability to the user's needs. **Hedonic factors** such as enjoyment related to use, attractiveness (size, physical appearance, anthropomorphism, etc.), and social intelligence (related to the robot/agent's ability to perform social behaviors, e.g., demonstrating traits associated with caring, intelligence, empathy, human-like communicative capacities, and companionship). **Context of use factors** such as social pressures, status gain, trust, privacy, previous experience, prior expectations, perceived behavioral control in relation to the data being recorded and stored. Situational factors, such as, the circumstances and the time of the day under which interactions with the agent/robot took place (influencing participants' experiences), the location, the presence of others in the house, the user's mood at the time of the interaction). **User characteristics factors** a such as age, sex, general level of interest in technology, and type of household. All of these factors will contribute to the domestication of the system (robot/agent), i.e. the long-term user acceptance of the assistive technology. Domestication requires an initial acquaintance of the system's functions and interactive behaviors, the incorporation of it into user's daily life, continued use of it, and the generation of ideas for future improvements. According to De Graaf et al. [6] hedonic rather pragmatic motivations appear to have impact more on the elders' acceptance of social assistive devices in their homes.

The roles of key moderating factors such as age and other sociodemographic variables, previous experience with technology, and user's representation of assistive technology on long-term acceptance are examined in-depth in the following section.

2.2.1 Age and other Sociodemographic Factors

The impact of user's age on the credibility and reliability of assistive social technologies is controversial and, despite its possibility of moderating the influence of all the factors considered as affecting user acceptance, age has received scant attention by the related literature [15].

In this context controversial results have been highlighted. A portion of the current literature attributed to Seniors the following characteristics:

- Being less willing to use assistive technology, with positive attitude decreasing as age increases [26, 33-36]
- Being suspicious of new technology (in contrast to younger people, who are more confident); having reservations about using robots/agents seen as futuristic advanced technologies that can be difficult to master, and potentially will produce changes in the socio-physical aspects of their home environment [33, 35, 37-39]
- Being reluctant and even opposed to technological advances accompanied by their being less technologically literate; having an aversion toward using such devices because incompatible with their "generational habitus" [38, 40]
- Fearing the use of robots/agents because of their not-knowing and not-mastering some technologies although some may have positive attitudes toward service robots to the extent the proposed assistive technology function without the user needing help from others or a large amount of training) [39]
- Being less inclined than younger people to adopt trial and error strategies when difficulties arise in operating the technology, and consequently seeking help of experts and feeling inappropriate themselves [9, 33, 35, 38]

On the other hand, other studies found no significant differences in regard to age and attitudes toward technology [41] and noted that one's chronological age becomes less important than his or her need. That is, when users who are older have specific needs that a particular technological device can help them meet, their level of acceptance increases and negative effects related to age decrease and lose relevance [35, 38, 42, 43]. Conversely and in agreement with the TAM framework, if the elderly person fails to experience the assistive robot/agent as helpful or useful, is less likely to agree to its presence in the home [41].

Regarding technology acceptance and gender, with respect to men, women have been described as:

- Less likely than men to accept and use assistive technologies; men were found to have a more accepting attitude about robotic technology and its use [24, 34, 35, 44-46]
- Expecting that learning to use assistive technologies is more demanding [47]
- Being more skeptical and afraid of becoming dependent upon the assistive technology [35, 38]
- Preferring a greater distance between themselves and the robotic device and uncertain about talking to a nonhuman device [35, 38]
- Less inclined than men to anthropomorphize because they do not perceive the robot/agent as an autonomous person [35, 48]
- Being more conscientious in regard to monitoring their own health with the help of assistive technology [35, 36]
- Being interested in specific features of the robot [33, 49]

Conversely, other evidence described women as more interested than men in interacting with a robot/agent, viewing the robot as a human male, and having a more positive attitude toward establishing a relationship with a virtual companion [33, 50-52]. It was also found that some gender differences can be misleading without reference to age. [15].

In regard to educational level, people with lower levels of education have been described as less confident about their ability to master a novel device and as reporting greater resistance and negativity toward technology than those who had finished their high school education and those who had earned a college degree [9, 38]. Similarly, for older adults, more education was linked to greater acceptance in regard to using technology to solve everyday problems but with less openness in perceiving a robot/agent as a social entity [9, 26, 35]. However, other evidence does not support moderating effects of the education level on older users' technology acceptance [53].

2.2.2 The Role of Experience with Technology

Direct experience or lack of familiarity with technology were described as playing relevant roles in influencing user attitude and preference regarding an assistive device [33, 35, 54, 55]. Being familiar with various forms of technology was found to affect users' attitudes about these systems and increase their adoption of technology no matter of the age [26, 56-58].

Furthermore, users prior experience in using technology, is a deciding factor in their acceptance of new technological devices. This finding is considered as moderating the role of age and other sociodemographic variables [35]. In other words, it has been argued that those who are younger may be more likely than older individuals to accept robots/virtual agents since they are more familiar with them [35]. The moderating effect of having experience using technology hold true regarding gender and educational level as males usually have greater experiences using technology than females do, and similarly, those with less education seem to have less experience with technology [35]. Some research has confirmed that males who have had more experience with computers perceive robots as easy to use [26].

However, it should be noted that other evidence described no significant associations between user's level of acceptance and willingness to use assistive technology and gender, education, age, or participants' prior experience using technology, either in using a virtual agent [23] or using and interacting with assistive robotic technology [57, 59]. Such discrepancies among several studies demonstrates the complexity to isolate from these robot/agent human interactions the effects of sociodemographic and behavioral factors on user acceptance [35].

2.3 The Barrier of User's Representation of Social Assistive Technology

A critical role in user's acceptance is acknowledged to be the user's technology device representation, which can serve as a barrier to the use of a new device in several ways.

2.3.1 Stigma, Threat to Autonomy and Infantilization

A significant impediment to user acceptance is the possibility to stigmatize the use of robots/agents [40]. This stigma derive from the belief of some Seniors that the needing to be assisted by a robot/agent can be interpreted as an emblematic aging, characterized by loneliness, and mental and/or physical declines [40, 60, 61]. This perception leads older individuals to refuse the use of social assistive technology striving to appear in good shape, active, and independent, i.e., not yet in need of an assistive device [35, 60, 62]. For these Seniors assistive technologies were considered to assist people handicapped, dependent on others, frail or ill, or living alone without family or friends to assist them [40].

In addition, some Seniors perceive assistive technology devices as threatening their autonomy and self-image [63]. This population fears that using assistive technology potentially reduces their current skills and abilities and induces dependence on machines [64]. Therefore these Seniors felt that being treated condescendingly by a machine which limits their executive control in relation to daily as well as longer-term decisions diminishes or undermines their autonomy and result in an infantilization [63, 65]. As an example, some Seniors feel disheartening and encouraged to adopt regressive behaviors when proposed to use dolls or stuffed toys, regardless of their therapeutic potential [65, 66].

Additionally, there is evidence that Seniors prefer to keep doing things on their own, and manage tasks difficult for them using adaptation and/or compensatory strategies rather than depending on something that might prevent them from making an effort [40]. Even in the case of cognitive impairment, this attitude was found to prevent some participants from considering themselves as potential users of assistive technologies [67].

2.3.2 Control and Privacy

Accepting assistive technology is highly correlated with issues of control and privacy.

The need and feeling of being able to control the device and predict its behavior has been described as a variable playing a crucial role in user acceptance [61, 68].

Seniors described a virtual companion as being acceptable to them if it serves proactively as an assistant whose actions can be set by a timer or initiated by the user. To them the assistant must be unobtrusive and able to be deactivated when the user chose to do so [6, 23, 69]. Seniors wanted to be able to control the companion and accept to integrate it into their environment if it behaves reactively rather than proactively [23, 62].

Another problem is related to the user's privacy because when a system is designed to assist the user in performing daily activities, the use of cameras or sensors is essential, but at the same time, the user's privacy should be respected [10, 66]. Specifically, older adults were found to express concerns about the use of cameras and the possibility that their interactions with the assistive device might be recorded for others to view [23]. To this aim, Seniors expressed concerns about feeling watched and invaded in their privacy [40, 61]. For these reasons, several authors suggested that video cameras should be able to observe only a predefined and restricted area and sensors should be activated only by the user [62].

In addition, it is crucial for Seniors to be able to access the video recordings delete all or parts of the data at their will [6, 23].

2.3.3 Fear of Dehumanization and Isolation

Seniors fear the use of assistive devices if such devices are intended to replace human presence and reduce human social contacts thereby further isolating them from family and friends [37, 40, 58, 66, 69, 70]. Similarly, the lack of authenticity of a companion device could also explain the unwillingness of elderly persons to adopt assistive technologies [67]. In particular, Seniors were found to express reluctance about using assistive devices that were perceived as having inauthentic expressions and offering artificial interactions [70]. As a result, even Seniors well-disposed to using robotic and virtual agent assistants, when asked to choose, expressed clear preferences for human assistance for specific tasks such as those related to personal care, taking medications, and leisure activities [71- 73].

Evidence suggested that the capacity of a virtual assistant to interpret a user's moods or emotions is negatively seen by Seniors which attributed these abilities uniquely to humans [23]. As consequences of these feelings, Seniors frequently expressed fears, regarding the dehumanization of our society, in terms of changing the fundamental role of humans, threatening the uniqueness of each person while caring of vulnerable people [40, 67, 70].

2.4 How to Assess a User's Attitude and Level of Acceptance

Considering the many differences among older persons, any design for a successful assistive device, as well as which type of device is selected, can be determined only after an accurate assessment of the potential user's needs and preferences, as well as her daily living arrangements [74]. Several critics remarked that professionals involved in creating and producing assistive technological devices, neglect to solicit the input of their end users relying on subjective, biased, and skewed interpretation of the feelings and requirements of the target population thus having a negative impact on the device's design [35, 60].

Therefore, there is a critical need to survey elderly persons and accurately represent their requirements, expectations, and values in regard to emergent technologies aiming to assist them. Doing so can undoubtedly provide valuable information about how Seniors conceptualize these assistive devices and which design may be successfully adopted [75, 76]. In order to understand beneficial functionalities and meeting Seniors daily needs in the application domain a combination of quantitative data-collection methods, direct observations, semi-structured interviews, focus groups, were adopted [40].

Quantitative methods have produced several questionnaires and user-opinion measures to explore Seniors' perceptions, attitudes, and expectations about assistive devices.

The **TAM measurement scale** [12] measures two variables hypothesized to be determinants of technology usage, i.e., perceived usefulness (PU) and perceived ease of use (PEOU). These two constructs were each measured through 6 items exemplified in the form of statements expressing the respondent's likelihood to adopt a given behavior toward the assistive device being assessed. Each respondent's answer is measured by through two, 7-point Likert scales, one with likely–unlikely endpoint adjectives and the other, reversed in polarity, with improbable–probable endpoints. This questionnaire was adapted in one study to measure user acceptance of a robotic system by evaluating the PU and PEOU of different functionalities offered by the proposed robot [77].

The **TAM2 measurement scale** comprises 26 items measuring four constructs encompassed in the TAM2 model, namely intention to use (2 items), perceived usefulness (4 items), social influence (including subjective norms, 2 items), voluntariness (3 items), image (3 items), and instrumental cognitive processes (including job relevance, 2 items), output quality (2 items), results' demonstrability (4 items), and perceived easiness of use (4 items) [14]. All items were measured on a 7-point Likert scale, from 1 = strongly disagree, 2 = moderately disagree, 3 = somewhat disagree, 4 = neither disagree nor agree, 5 somewhat agree, 6 = moderately agree, to 7 = strongly agree.

The **UTAUT questionnaire** was based on 7 constructs: performance expectancy (4 items), effort expectancy (4 items), attitude toward using technology (4 items), social influence (4 items), facilitating conditions (4 items), self-efficacy (4 items), anxiety (4 items), and intention to use (3 items) [15].

All items were measured on a 5-point Likert scale, asking participants to indicate their level of agreement to statements from 1 = strongly disagree, to 5 = strongly agree.

The items were adapted by several authors, and the original 31 items were modified on the basis of the aims of their studies [15, 45, 46].

The subsequently extension UTAUT2, substituted for the constructs of anxiety attitude toward using technology and self-efficacy, the constructs of hedonic motivations (3 items), price values (3 items), and habits (4 items) which were considered more appropriate factors affecting technology acceptance. The final questionnaire was composed of a 29 items measured (except for the "use behavior" item, which was not specified) with a seven-point Likert scale, ranging from "strongly disagree" to "strongly agree" [11].

The above questionnaires and associated theories from which they developed do not account of users' ages and in particular do not consider either Seniors as end users, or assistive technologies such as robots and virtual assistants.

The **Almere model** aimed to assess users' acceptance of assistive social robots designed for elder-care environments [25]. The questionnaire was based on 13 constructs: anxiety, attitude towards technology, facilitating conditions, intention to use, perceived adaptiveness, perceived enjoyment, perceived ease of use, perceived sociability, perceived usefulness, social influence, social presence, trust and intention to use. So far, it is the only psychological scale that purports to assess users' perceptions of social robots in human–robot interactions specifically considering Seniors [22, 25]. All the 41items are measured on a 5-point Likert-type scale ranging from 1 to 5 (totally disagree, disagree, don't know, agree, totally agree). Higher scores indicate higher acceptance [25].

It should be noted that, while the final version of the questionnaire was being developed, questions concerning acceptance and relying upon the above-mentioned constructs were adopted in several studies [24, 40]. In addition, modified versions of the original questionnaire referring to several of the constructs theorized in the Almere model were used to assess elderly users' acceptance of an assistive social-agent system [61, 78].

The **Person-Robot Complex Interactive Scale** (PRCIS) was proposed to investigate human – robot interactions; it considers human diversity as well as diversity among types of robotic systems [79, 80].

The PRCIS has four sections: two consider the instructor's evaluation and two target the participant's assessment. The two sections aiming to assess the instructor's overall evaluation of human–robot interactions, use a multiple-choice scale. This scale considers facets of participant's behaviors, from disruptive to interactive, overall verbal and nonverbal intensity of communication, engagement level, and prevailing mood. In particular, the instructor assesses the participant's individual communication style with the robotic device assessing parameters associated to the nonverbal interactions (including tactile and manipulative patterns), the participant's verbal responses (whether and to what degree she interacts with the robot using words or utterances), and emotional aspects of the participant's communicative interactions (positive or negative reactions to the robot's behavior).

The two sections involving the participant's evaluation of the robotic system consider participant's likes and dislikes of the robot interactional abilities, novelty of the experience, evaluation of the system's features, identified advantages and drawbacks of the system, and any prior experiences with this type of technology.

All of the PRCIS's subscales take into consideration negative and positive displays and measure behaviors using a 5-point Likert-type assessment. Moreover, the use of open-ended questions provides the opportunity to express feelings on the perceived pros and cons of the robotic system [79, 80].

The **Robot Attitude Scale** (RAS) comprises 12 dimensions designed to measure respondents' attitude toward robotic systems rated on a scale from 1 to 8: safeness/danger of the robotic system, reliability/unreliability, friendliness/unfriendliness, simple/complicated, usefulness/uselessness, strong/fragile, interesting/boring, trustworthy/untrustworthy, advanced/basic, easy to use/difficult to use, and helpful/unhelpful). Lower scores represent more-positive perceptions [33, 59, 81].

The **Negative Attitude Towards Robots Scale** (NARS) [82, 83] was developed to assess respondents' general attitudes about robotic systems (before human–robot interaction studies were conducted with the respondents). This scale has 14 items categorized as three subscales: negative attitude toward situations and interactions (6 items); negative attitude toward robots' social influence (5items); and negative attitude toward emotional interactions with robots (3 items) [78].

The **Robot Anxiety Scale** (RAS) [83, 84] was developed to determine and measure state-like anxiety that may be evoked by robots in real and imaginary human robot interaction situations. This scale comprises 11 items grouped into three subscales: anxiety toward communication capacity of robots (3 items); anxiety toward behavioral characteristics of robots (4 items); and anxiety toward discourse with robots 4 items).

The **Perception to Humanoid Scale** (PERNOD) comprises 33 items designed to measure people's impressions of a humanoid robot. This humanoid-oriented scale is based on five fundamental dimensions: familiarity, utility, motion, controllability, and toughness [85].

The **Godspeed Questionnaire Series** measures users' opinions and perceptions of a robot on 5 constructs: anthropomorphism (5 items), animation (6 items), likeability (6 items), perceived intelligence (5 items), and perceived safety (3 items). The items in the different categories were interleaved and a 5-point Likert-type scale was used [86].

The **Robot Opinion Questionnaire** was developed to evaluate Seniors' attitudinal acceptance of robots. It is a revision of the TAM technology-acceptance scale that is specific to robots. The questionnaire has 12 items measured by a 7-point Likert-type scale (1 = extremely unlikely, 4 = neither unlikely nor likely, 7 = extremely likely). Sample items include: "My interaction with a robot would be clear and understandable"; "I would find a robot useful in my daily life"; and "Using a robot would make my daily life easier" [72].

Several studies adopted measurement tools from social and clinical psychology in order to assess user–agent relationships. These scales are described below.

The **Comfort from Companion Animals Scale** is a 11-item questionnaire, designed to measure respondents' attachment to the comfort they perceive in reflection on from a pet robot exploited as companion [87]. This scale is generally used to evaluate people's close companionship with their pets. It was then considered useful also for measuring similar feelings toward virtual pets or pet-like robots [88]. The level of agreement/disagreement toward the 11 items was measured on a 4-point Likert-type scale ranging from strongly agree (4 points) to strongly disagree (1 point).

The **Lexington Attachment to Pets Scale** (LAPS) [89] is a 23-item questionnaire originally designed for evaluating attachment to pets. The 23 items are grouped into three subscales (general attachment, people substitution, and animal rights/animal welfare) and was appropriately modified for evaluating people's attachment toward interactive robotic pets [90].

The **Companion Animal Bonding Scale** [91] is an 8-item behavioral scale evaluating child–animal interactions. It evaluates the acceptance of a robot an in-home companion by Seniors living independently at home (i.e., aging in place) [92].

The **Working Alliance Inventory** (WAI) is a questionnaire used in psychotherapy to assess the quality of a client–therapist relationship [93, 94]. It consists of 36-items exemplified into three constructs: a) bond, establishing the degree of liking and trust between the assistants and people in need (e.g., "My relationship with [name of virtual agent] is very important to me"); b) task, considering the degree of both helper and receiver in performing therapeutic tasks (e.g., "The things that [name of virtual agent] is asking me to do/ don't make sense"); and c) goal, assessing the extent the assistant and assisted person agree on the goals of the therapy (e.g., "[name of virtual agent] perceives accurately what my goals are"). The WAI items have been slightly modified in order to be appropriate for referring to a robotic device. For example, the statement "I understand (person) and she understands me" was modified as "I understand [name of virtual agent] and she understands me, at least in the best way she can." [95].

The **Positive and Negative Affect Schedule** (PANAS) was used to measure positive/negative emotions during a human-robot device interaction PANAS consists of 10 positive and 10 negative words related to emotions (e.g., enthusiastic, afraid, etc.) rated on a 5-point scale from ''very slightly or not at all'' to "very much". The respondent's rate the PANAS words in response to the question: How do you currently feel about using a health care robot? [59, 96]

A modified version of the **Social Interaction Scale** [97] was used to evaluate participants' ratings of their level of enjoyment while interacting with a robotic device. Specifically, participants were asked to indicate how much they enjoyed this interaction; how was it was smooth, natural, and relaxing; their desire to interact with the device again; the extent to which the interaction was forced, strained, or awkward; the extent to which they feel to control the interaction with the device; how intimate they perceived the interaction; the extent to which the interaction was satisfying, pleasant. [44, 97].

The dyadic interaction paradigm developed by Ickes et al. [98] to assess interactions between human dyads was adapted to collect users' (not necessarily older users) thoughts and feelings during interaction with a robotic device [96]. The frequencies, valence (positive or negative) and content of each thought and feelings were evaluated [99].

In addition, human acceptance of virtual agents and robots as well as user preferences, perceptions, opinions, levels of satisfaction, and perception of attractiveness and engagement with such agents have been also investigated using single or multi-item scales, questionnaires with multiple-choice and open-ended questions, and semi-structured interviews developed ad hoc according to the aims of the particular research [6, 10, 23, 30, 39-41, 59, 64, 67-72, 93, 95, 100-113].

Similarly, focus group interviews or recordings of human–agent interactions were exploited as methods for exploring how users envision their interactions with robotic assistants or investigate opinions and expectations of older people about their appearance and functions [23, 61, 62, 67, 68, 70, 81].

Conclusions

An accurate and personalized evaluation of Seniors' needs, psychological functioning and current life context is required to successfully incorporate assistive social technologies in Seniors' everyday life. Currently, there is no clear vision of which Seniors' expectations concerning robot characteristics and how to personalize/customize social assistive technology configurations, fits all possible application's scenarios [61]. Therefore, highly flexible systems need to be implemented. The complex interactions among sociodemographic, and cultural factors, such as personal experience with technology, preferences, robot's appearance, usefulness, costs and cognitive efforts for robot uses entail the demand of a deep and accurate analysis of each use case, in order to achieve Seniors' acceptance of such devices [35].

Particular attention should be devoted to the stigma derived from associating physical and cognitive declines, dependence on others, frailty and illness to the use of robots/agents, as well as, threatening their autonomy and self-image.

The major risk is infantilization and loss of dignity. Seniors fear that assistive devices limits their executive control and undermine their autonomy. To overcome these feelings, Sharkey [114] proposed the "capability approach." This approach allows for the identification of situation where robotic devices can potentially enhance Seniors' dignity by expanding their capabilities to autonomously handle daily activates and be engaged in social relationships. Therefore, any intelligent autonomous system that has been implemented to assist elders must be equipped with functionalities that do not mishandle their intelligence but supports their well-being. These functionalities must provide a sense of physical security, support different experiences, provide care for recreation activities and encourage sensory experiences, ideas and creativity [63, 114]. Similarly, appropriate countermeasures for data protection, security and privacy must be accounted for, to ensure Seniors' acceptance and incorporate such technologies into their home environments [63, 115].

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Putting Humans Back in the Loop: A Study in Human-Machine Cooperative Learning

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Abstract: This paper introduces a novel approach to human-machine collaborative learning that allows for the chronically missing human learnability in the context of supervised machine learning. The basic tenet of this approach is the refinement of a human designed software model through the iterative learning loop. Each iteration of the loop consists of two phases: (i) automatic data-driven parameter adjustment, performed by means of stochastic greedy local search, and (ii) human-driven model adjustment based on insights gained in the previous phase. The proposed approach is demonstrated through a real-life study of automatic electricity meter reading in the presence of noise. Thus, a cognitively-inspired non-connectionist approach to digit detection and recognition is introduced, which is subject to refinement through the iterative process of human-machine cooperation. The prototype system is evaluated with respect to the recognition accuracy (with the highest digit recognition accuracy of 94%), and also discussed with respect to the storage requirements, generalizability, utilized contextual information, and efficiency.

Keywords: human-machine cooperative learning; digit recognition; stochastic search

1 Introduction

An important aspect of digital education relates to supporting the learner to acquire software development competencies. The main lines of research in this field include cost-effective simulation of programming environments [8, 20], dynamic adaptation of e-training [9, 36], human-machine interaction [31, 34] and collaborative learning [21, 22]. Recently, the research attention has been also devoted to developing specific digital teaching paradigms [5]. This paper makes a novel contribution to the field. It introduces an approach to human-machine collaborative learning that allows for the chronically missing human learnability in the context of supervised machine learning.

Deep learning has undoubtedly made a significant breakthrough in many scientific domains. One of the main reasons of the enormous popularity of neural networks is that they – at least in the manner usually practiced – do not require considerable domain expertise or human engineering [26]. The very term "learning" is somewhat misused in this context. Deep learning relates to the process of encoding statistical regularities from the training corpora into parameters, which operate by very different principles from those underlying human learning [38]. Modern deep neural networks may contain up to hundreds of millions of automatically adjusted parameters [26], and derive high-dimensional representations that are not interpretable by human. Therefore, although deep learning may result in very useful software artifacts, it does not contribute to human learnability of domain expertise.

This paper[1] considers the question of bringing the human back into the learning loop. It proposes an approach to making the process of software development more explanatory to the practitioner, while keeping some of the existing advantages specific to supervised learning. The proposed approach is demonstrated through a real-life study of automatic electricity meter reading in the presence of noise.

1.1 Main Idea and Outline

This paper makes contributions along two research lines. First, it introduces a two-stage approach to digit detection and recognition (cf. Section 2). The approach is cognitively-inspired to the extent that it integrates the dichotomy between the pre-attentive processing and the attentive processing that is present in the theories of human attention [7, 13, 24, 31, 32, 35]. It is also parameterized, and the number of free parameters is small enough that the model is analytically tractable by human. To this extent, this approach is non-connectionist.

However, it cannot be assumed that this approach is *per se* generalizable to the target domain. This leads to the second research line – iterative refinement of the approach through human-machine cooperation. This research line derives from iterative and incremental software development practices that belong to the folklore of computer science [25]. However, it is particularly focused on supervised learning, and on what we refer to as "iterative learning loop", represented diagrammatically in Fig. 1. Each iteration of the loop consists of two phases (cf. Section 3):

[1] This paper is a significantly extended version of [18].

- Automatic data-driven parameter adjustment, performed by means of stochastic greedy local search over a training corpus.
- Human-driven model adjustment based on insights gained in the previous phase.

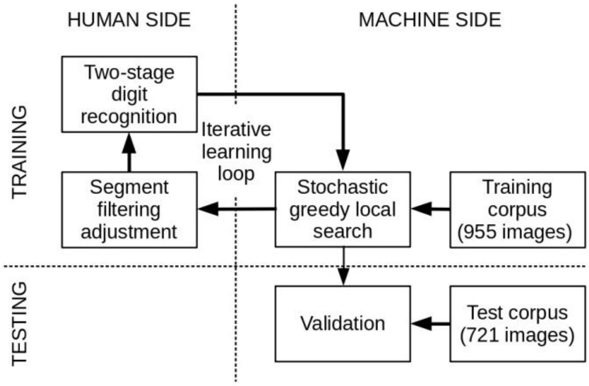

Figure 1

Diagrammatic representation of human-in-the-loop supervised learning

The main idea is to allow the practitioner to take advantage of automatic data-driven supervised learning – not only with respect to parameter adjustment (which is the usual case), but also to gain additional qualitative insights into the target domain. Thus, the iterative refinement of the approach to digit detection and recognition is both machine-driven and human-driven. The number of iterations is not predefined, i.e., the model is refined until it satisfies external requirements (in this paper, we describe two iterations).

After the iterative learning loop is completed, the model is validated on a test corpus. The paper ends with the discussion and conclusion (cf. Section 4).

2 Two-Stage Approach to Digit Recognition

The theories of human attention acknowledge that selective processing of sensory information has an important role in human cognition [2, 6]. However, they do not agree on the processing stage in which information are selected [32, 35]. The *early selection* view assumes that incoming sensory information are filtered in a processing stage prior to the stage of semantic interpretation, and that only the selected information is interpreted [7, 24]. The *late selection* view assumes that all sensory information is semantically interpreted, and that selection occurs in a later stage on the level of interpreted information [13]. A significant body of evidence supporting one or other of these views has been presented in this long-standing debate, which may imply that the early and late selections of sensor information do not necessarily exclude each other [32].

In line with this, we assume the view that selection of sensory information occurs in two processing stages (cf. [31]):

- Pre-attentive processing serves as the basis for perceptual grouping,
- Attentive processing allows for semantic integration.

In the considered real-life study of automatic electricity meter reading, the pre-attentive processing stage is devoted to detecting relevant numbers, i.e., rows of digits that represent rates, while ignoring irrelevant digits (e.g., an electricity meter serial number) and symbols. Each number detected in the pre-attentive processing stage separately undergoes the attentive processing stage, devoted to recognition.

Two-stage processing has already been applied in various approaches to the research problem of object detection and recognition. At the methodological level, these approaches usually apply data-driven statistically-based techniques, such as the Markov random field theory and maximum a posteriori principle [30], the AdaBoost algorithm [15, 29], the support vector machine [1], neural networks [28], etc. (a more extensive overview is given in [15]). Symbolic approaches are applied significantly less often [17].

However, at the practical level, the production of representative and balanced training corpora is a challenging task, especially in such cases when surface manifestations of noise in image vary significantly. In contrast to the dominant trend, the approach introduced in this section is feature-based, but still non-connectionist in the sense that it does not require an extensive training corpus.

To extract feature vectors that represent image segments, we refer to the normalized histogram of oriented gradients [10]. To estimate the similarity between the feature vectors, we apply the cosine similarity [12].

2.1 Feature Extraction

Let f be an image segment, and let $f(x, y)$ be the intensity of segment f at pixel (x, y). To compute the gradient of f at pixel (x, y), we apply the horizontal and vertical Sobel filters:

$$\nabla f(x, y) = \begin{bmatrix} \dfrac{\partial f(x, y)}{\partial x} \\ \dfrac{\partial f(x, y)}{\partial y} \end{bmatrix} = \begin{bmatrix} g_x(x, y) \\ g_y(x, y) \end{bmatrix} = g(x, y) \qquad (1)$$

This gradient vector can be equivalently represented by its magnitude $\|g(x,y)\|$ and gradient direction $\theta(x,y)$, i.e.:

$$g(x,y) = (\|g(x,y)\|, \theta(x,y)) \tag{2}$$

where the magnitude is approximated by:

$$\|g(x,y)\| = \sqrt{g_x(x,y)^2 + g_y(x,y)^2} \approx |g_x(x,y)| + |g_y(x,y)| \tag{3}$$

and the gradient direction is calculated as:

$$\theta(x,y) = \begin{cases} \arctan \dfrac{g_y(x,y)}{g_x(x,y)}, & if\ g_x > 0, \\ \arctan \dfrac{g_y(x,y)}{g_x(x,y)} + \pi, & if\ g_x < 0, \\ \dfrac{\pi}{2} \cdot \operatorname{sgn}(g_y), & if\ g_x = 0. \end{cases} \tag{4}$$

Gradient vector $\mathrm{g(x, y)}$ is further decomposed along n chain code directions, i.e., it is decomposed along a set of n elementary vectors rotated in increments of $2\pi/n$ (where n is an input parameter), having its gradient direction $\theta(x,y)$ approximated to the closet chain code direction. More formally, gradient vector $\mathrm{g(x, y)}$ is mapped onto a feature vector:

$$\alpha(x,y) = (a_0(x,y), a_1(x,y), \ldots, a_{n-1}(x,y)) \tag{5}$$

in which all elements but one are equal to zero, and the value of the nonzero element is equal to the gradient vector magnitude $\|g(x,y)\|$:

$$a_i(x,y) = \begin{cases} \|g(x,y)\|, & if\ i = \left\lfloor \dfrac{\theta(x,y) \cdot n}{2\pi} \right\rfloor, \\ 0, & otherwise, \end{cases} \tag{6}$$

for $0 \le i \le n-1$. Thus, a pixel at (x,y) is represented by an n-dimensional feature vector $\alpha(x,y)$. To represent entire segment f, it is partitioned into an $M \times N$ grid of rectangular cells:

$$B_0(f), B_1(f), \ldots, B_{M \times N-1}(f), \tag{7}$$

where M and N are input parameters. Each cell $B_i(f)$ is represented by an n-dimensional feature vector:

$$\beta_i(f) = (b_{i,0}(f), b_{i,1}(f), \ldots b_{i,n-1}(f)), \tag{8}$$

calculated as the sum of all feature vectors that represent the pixels belonging to the given cell, i.e.:

$$b_{i,j}(f) = \sum_{(x,y)\in B_i(f)} a_j(x,y), \tag{9}$$

where $0 \le i \le M \times N - 1$ and $0 \le j \le n-1$

Feature vector $\hat{\chi}(f)$ that represents segment f is generated in two steps. First, all cell feature vectors $\beta_0(f), \beta_1(f), \ldots, \beta_{M\times N-1}(f)$, are concatenated:

$$\chi(f) = (c_0(f), c_1(f), \ldots, c_{n\times M\times N-1}(f)), \tag{10}$$

where

$$c_i(f) = b_{\left\lfloor \frac{i}{n} \right\rfloor, (i \bmod n)}(f), \tag{11}$$

and then each element in vector $\chi(f)$ is normalized with respect to the entire segment, i.e.:

$$\hat{\chi}(f) = (\hat{c}_0(f), \hat{c}_1(f), \ldots, \hat{c}_{n\times M\times N-1}(f)), \tag{12}$$

where:

$$\hat{c}_i(f) = \frac{c_i(f)}{\sum_{k=0}^{n\times M\times N-1} c_k(f)^2}, \tag{13}$$

and $0 \le i \le n \times M \times N - 1$. An image segment is represented by a feature vector whose size (i.e., $n \times M \times N$ elements) is constant and does not depend on the size of the segment. This enables the comparison of segments of different sizes.

2.2 Feature Vector Similarity

Let $\hat{\chi}(f_1)$ and $\hat{\chi}(f_2)$ be feature vectors that represent image segments f_1 and f_2, respectively. As a measure of segment similarity, we apply the cosine similarity:

$$sim(f_1, f_2) = \frac{\hat{\chi}(f_1)\cdot\hat{\chi}(f_2)}{\left\|\hat{\chi}(f_1)\right\|\cdot\left\|\hat{\chi}(f_2)\right\|} = \frac{\sum_{i=0}^{n\times M\times N-1} \hat{c}_i(f_1)\hat{c}_i(f_2)}{\sqrt{\sum_{i=0}^{n\times M\times N-1} \hat{c}_i(f_1)^2}\sqrt{\sum_{i=0}^{n\times M\times N-1} \hat{c}_i(f_2)^2}} \tag{14}$$

Since all elements in feature vectors are nonnegative, $sim(f_1, f_2)$ will always be in range $[0,1]$ – the higher the score, the more similar the feature vectors.

2.3 Pre-attentive and Attentive Processing

The electricity meter reading is conducted in the following stages: (i) preparatory stage (i.e., image pre-processing), (ii) pre-attentive processing (i.e., number detection), and (iii) attentive processing (i.e., number recognition). The image pre-processing includes:

- Color to grayscale conversion, according to the ITU-R recommendation BT.709-6 (06/2015) [23],
- Contrast stretching, i.e., image enhancement by means of increasing the dynamic range of its gray levels [19, pp. 85-86],
- Adaptive global thresholding [33, pp. 120-121], i.e., binarization of the image by means of separation of light and dark regions.

The other two stages are described in more detail in the following subsections.

2.3.1 Pre-attentive Processing: Number Detection

The introduced approach is feature-based. Each digit $d \in \{0,1,\ldots,9\}$ is described by a feature vector $\hat{\chi}(d)$ extracted from a binarized image of digit d, as described in Subsection 2.1. Let T be the set of all ten ground-truth feature vectors:

$$T = \{\hat{\chi}(0), \hat{\chi}(1), \ldots, \hat{\chi}(9)\}. \quad (15)$$

In the pre-attentive processing stage, a sliding window is used to search through the image and perform early selection of relevant image segments. For each sliding window segment f, its feature vector $\hat{\chi}(f)$ is generated and compared to the ground-truth feature vectors in T. If the maximum similarity value of $\hat{\chi}(f)$ with each one of the ground-truth feature vectors is greater than the predefined threshold value λ_1 (which is also an input parameter), i.e.,

$$\max_{t \in \mathrm{T}} sim(\hat{\chi}(f), t) > \lambda_1, \quad (16)$$

segment f is marked as potentially containing a digit, and added to set P.

It should be noted that the mapping of relevant digits in the input image onto segments in set P is not intended to be bijective. The size and step of the window are input parameters. Depending on their values, segments stored in P may overlap (i.e., they may contain the same digit), or a digit in the input image can remain undetected. To illustrate this, we deliberately selected non-optimal values of the size and step of the sliding window (i.e., the window size is smaller than optimal, and the step is greater than optimal). The result is shown in Fig. 2. For the purpose of presentation, the width and height of all images are scaled up by the factor of two, and the rectangles that designate segments are automatically generated by the prototype system. The grayscale input image is given in Fig. 2(a). The segments in P are depicted in Fig. 2(b). Some segments are incorrectly marked as containing a digit, while some digits were not detected at all. However, a segment that contains the entire number can be determined as the *minimum rectangular segment* that contains all segments in P, as depicted in Fig. 2(c).

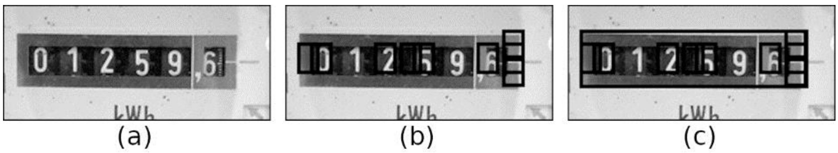

Figure 2
Number detection in the pre-attentive processing stage: (a) the grayscale input image, (b) the segments detected as containing digits, (c) the segment containing the entire number (images adopted and adjusted from [18])

In addition, since an electricity meter may contain more than one row of relevant digits, after the window slides through the entire image, set P is partitioned so that each subset $\mathrm{P}_i \subseteq \mathrm{P}$ contains digits that belong to a separate number. For the purpose of this contribution, we assume that rows of digits are presented one below the other (which is often the case). We consider that segments p_i and p_j from set P are related (i.e., they contain digits belonging to the same number) if they overlap along y-axis or if there is another segment $p_k \in \mathrm{P}$ such that p_k is related both to p_i and p_j. This relation between segments is an equivalence relation, and it is used to partition set P:

$$(\mathrm{P} = \bigcup_i \mathrm{P}_i) \wedge (\forall \mathrm{P}_i, \mathrm{P}_j \in \mathrm{P})(\mathrm{P}_i \neq \mathrm{P}_j \Rightarrow \mathrm{P}_i \cap \mathrm{P}_j = \emptyset), \tag{17}$$

where each subset $\mathrm{P}_i \subseteq \mathrm{P}$ relates to a separate number. This is illustrated in Fig. 3(a,b). The grayscale input image given in Fig. 3(a) contains two relevant numbers, i.e., the electricity meter has two rates. The set of segments detected by the sliding window is partitioned into two subsets: P_1 and P_2 (cf. Fig. 3(b)). The image segment containing the first number is determined as the minimum rectangular segment that encapsulates all segments in P_1. Similarly, the minimum rectangle segment that encapsulates all segments in P_2 relates to the second number.

In general, after the completion of the pre-attentive processing stage, a set of segments containing relevant numbers in the input image is extracted:

$$\{f_{num_1}, f_{num_2}, \ldots, f_{num_k}\}. \tag{18}$$

Each of these segments separately undergoes the attentive processing stage.

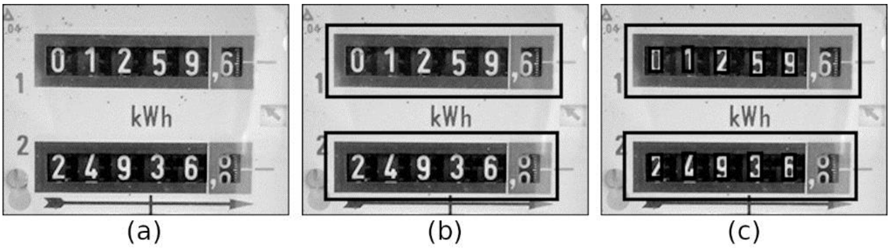

Figure 3
(a) The grayscale input image, (b) number detection in the pre-attentive processing stage, (c) number recognition in the attentive processing stage (images adopted and adjusted from [18])

2.3.2 Attentive Processing: Number Recognition

In the attentive processing stage, the late selection performed over the segments containing relevant numbers includes the following steps:

(i) Segmentation. Each segment f_{num_i} is further segmented by applying the graph-based image segmentation algorithm introduced in [14]. This segmentation algorithm is adapted only with respect to the threshold value used to merge segments – we use a fixed threshold value μ passed as an input parameter.

(ii) Segment filtering. We discard subsegments whose dimensions (relative to the size of the containing segment f_{num_i}), black/white pixel ratios or height-to-width ratios are not in the expected ranges for a digit. It should be noted that the segment filtering conditions are not algorithmically-driven but rather based on the authors' qualitative and inherently limited insights into the domain problem. Therefore, they are subject to further refinement, as described in Section 3.

(iii) Segment classification. For each remaining subsegment f', its feature vector $\hat{\chi}(f')$ is extracted and compared to the ground-truth feature vectors in T (cf. Eq. (15)). If the maximum similarity value of $\hat{\chi}(f')$ with each one of the ground-truth feature vectors is greater than the predefined threshold value λ_2, i.e.,

$$\max_{t \in \mathrm{T}} sim(\hat{\chi}(f'), t) > \lambda_2, \tag{19}$$

the segment is recognized as containing digit $dig(f')$, where:

$$dig(f') = \arg\max_{t \in \mathrm{T}} sim(\hat{\chi}(f'), t). \quad (20)$$

E.g., when two segments designated in Fig. 3(b) are passed to the attentive processing stage, the recognition results are indicated in Fig. 3(c). The digits after the decimal points are deliberately ignored, in accordance with the external requirements.

3 Iterative Learning Loop

The approach to digit detection and recognition introduced in Section 2 is subject to refinement through the iterative process of human-machine cooperative learning, combining automatic data-driven parameter adjustment with human-driven model adjustment (cf. Subsection 1.1).

The image corpora used in the iterative learning loop (and in the subsequent evaluation of the system, cf. Section 5) contain real-life electricity meter images with significant noise and incompleteness from various sources. Electricity meters are inconsistently illuminated, physically damaged (e.g., scratched glass) and obscured by dirt or dust. All the images were captured by naïve operators using standard Android-based phones. The *training corpus* consists of 955 images containing only one rate (i.e., one row of relevant digits and the surrounding context, similarly as in image given in Fig. 2). This corpus is used for automatic data-driven parameter adjustment. The *test corpus*, used for the purpose of evaluation, is described in Section 4.

Table 1

Parameters – marked with * if they are actually optimized

Parameter	
n - number of elements in a feature vector representing a pixel, cf. Eq. (5)	*
$M \times N$ - dimension of a grid of rectangular cells, cf. Eq. (7)	*
Dimension of the sliding window	
Steps of the sliding window along the x and y axes	
λ_1 - threshold for digit detection in the pre-attentive processing stage, cf. Eq. (16)	*
μ - threshold for graph-based segmentation in the attentive proc. stage, Sec. 2.3.2	*
λ_2 - threshold for digit recognition in the attentive processing stage, cf. Eq. (19)	*

3.1 Stochastic Greedy Local Search

The approach to digit detection and recognition is parameterized by a set of ten parameters (cf. Table 1) which are subject to data-driven optimization. The space of possible parameter assignments is too large for an exhaustive search. However, states in the search space are full assignments to all the parameters, which allows for applying a stochastic greedy local search algorithm. Similarly, as in deep learning approaches, the objective function is seen as a hilly landscape in the multidimensional space of parameter values [26], and therefore we apply an adapted hill-climbing algorithm with random restart [11, 37]. The algorithm is specified in Fig. 4 as a higher-order function, and its main idea may be described as follows.

Hill-climbing with random restart

Input: number or random restarts: r,
parameter domains: $D_0, D_1, \ldots, D_{n-1}$,
fitness function $h: D_0 \times D_1 \times \cdots \times D_{n-1} \to \Re$,
mutation oper.: $g: (D_0 \times D_1 \times \cdots \times D_{n-1}) \to \wp(D_0 \times D_1 \times \cdots \times D_{n-1})$.

Output: optimized instantiation of parameters for the fitness function:
$(p_0, p_1, \ldots, p_{n-1})$, where $(\forall\, 0 \le i < n)(p_i \in D_i)$.

Algorithm:

$E = \emptyset$
$\mathit{for}\ i = 0\ \mathit{to}\ r\ \mathit{do}$
  $x = (\mathit{rand}(D_0), \mathit{rand}(D_1), \ldots, \mathit{rand}(D_{n-1}))$
  $\mathit{search} = \mathit{true}$
  $\mathit{while}\ (\mathit{search})\ \mathit{do}$
    $x' = \arg\max_{y \in g(x)} h(y)$
    $\mathit{if}\ (h(x) < h(x'))\ x = x'$
    $\mathit{else}\ \mathit{search} = \mathit{false}$
  $\mathit{end\_while}$
  $E = E \cup \{x\}$
$\mathit{end\_for}$
$\mathit{return}\ \arg\max_{x \in E} h(x)$

Figure 4
Hill-climbing with random restart

The hill-climbing:

1. The greedy local search starts from a randomly chosen instantiation of parameters. We refer to it as the current instantiation x .

2. For the given current instantiation x, a set $g(x)$ of neighboring instantiations is generated. Let x' be the most fit instantiation in set $g(x)$.
3. If x' is more fit than x, then x' becomes the current instantiation, and the algorithm goes back to Step 2. Otherwise, the current instantiation is selected as a candidate for optimal solution.

Multiple random restart: To reduce the probability of getting stuck in a local extremum, the hill-climbing is restarted from finite number of different, randomly selected instantiations or parameters. Each run of the hill-climbing algorithm generates a candidate for optimal solution. After multiple restarts of the algorithm are completed, the most-fit candidate is selected as optimal solution.

Mutation (local changes in the search space)

Input: instantiation of parameters: $x = (p_0, p_1, \ldots, p_{n-1})$,
parameter domains: $D_0, D_1, \ldots, D_{n-1}$.

Output: set of n instantiations of parameters.

Algorithm:

$G = \emptyset$

$for\ i = 0\ to\ n-1\ do$

$\quad for\ j = 0\ to\ n-1\ do$

$\quad\quad if\ (i \neq j)\ x'[j] = x[i]$

$\quad\quad else\ x'[j] = v \,\big|\, v \in D_j \wedge v \neq x[j]$

$\quad end\_for$

$\quad G = G \cup \{x'\}$

end_for

$return\ G$

Figure 5
Mutation (local changes in the search space)

We use the following input arguments to the hill-climbing algorithm.

(i) Number of random restarts is set to five.

(ii) Parameters. Not all parameters given in Table 1 are actually optimized. The dimension of the sliding window and the steps of the sliding window along both the axes were predefined in line with the external requirements (cf. the discussion point on efficiency in Section 4). In addition, the threshold value for digit detection in the pre-attentive processing stage is considered to be equal to the threshold value for digit recognition in the attentive processing stage. The complete instantiation of the fitness function is represented as a set of parameters marked with * in Table 1.

(iii) The fitness h of a given instantiation of parameters is defined as the number of training samples that are recognized correctly and completely.

(iv) The mutation operation is defined in Fig. 5. Mutation of a given instantiation of parameters $x = (p_0, p_1, \ldots, p_{n-1})$ generates a set of n new instantiations, each of which differs from initial instantiation x in only one parameter value, i.e., mutation involves only local moves in the search space.

3.2 Learning through Human-Machine Cooperation

Each iteration of the learning loop includes automatic data-driven parameter adjustment, followed by human-driven model adjustment. We describe two iterations conducted in the study.

Iteration 1 – Automatic data-driven parameter adjustment: In the first iteration, the parameters are automatically optimized based on the introduced hill-climbing algorithm and the training corpus. At the digit level, 94% digits are correctly recognized, 3.16% incorrectly recognized, and 2.84% not detected. The confusion matrix is given in Table 2. At the number level, 67.02% images are completely recognized.

Table 2

Confusion matrix in the first iteration

	0	1	2	3	4	5	6	7	8	9	ND	Total
0	628	2	0	0	0	0	4	0	7	1	22	664
1	22	452	0	0	0	0	1	0	6	5	17	503
2	0	0	399	0	8	0	0	7	1	0	11	426
3	0	0	1	434	2	0	0	0	10	3	16	466
4	0	0	0	0	446	0	0	3	2	0	17	468
5	1	0	0	1	0	404	3	0	4	4	14	431
6	8	0	0	0	0	1	430	0	10	0	8	457
7	0	0	3	0	0	0	0	440	0	0	10	453
8	2	0	0	5	0	1	8	0	442	3	10	471
9	1	0	0	4	0	1	2	0	4	422	11	445
INS	78	19	15	15	29	7	23	6	95	34	-	321

INS – segment incorrectly recognized as a digit; ND – digit not detected

Iteration 1 – Human-driven model evaluation and adjustment: The analysis of the system's performance shows that, out of 4784 digits, 136 digits (i.e., 2.84%) are not detected. On the other hand, the number of segments incorrectly recognized as digits is more significant – 321 segments (which equals to 6.71% of all digits) – and affects the accuracy of the system more intensively. Thus, a new insight into the domain problem emerges, which would otherwise remain hidden because it is not directly related to the parameter adjustment: the segment filtering (cf. point (ii) in Subsection 2.3.2) is the critical point of the system. It is clear that the segment filtering conditions should be adapted accordingly. However, their modification is a trade-off. By tightening the segment filtering conditions, the number of segments incorrectly recognized as digits will decrease, but it can be also expected that the number of digits that are not detected will increase. Therefore, the conditions were modified by the authors with the intention to achieve a balance between these two confronting factors. In addition, this modification may affect the appropriateness of the parameter values automatically derived in the previous phase. To address these issues, the second iteration of the learning loop is started.

Iteration 2 – Automatic data-driven parameter adjustment: In the second iteration, the parameters are again automatically optimized. The optimization resulted in the same instantiation of parameters as in the first iteration, and the confusion matrix is given in Table 3.

Table 3
Confusion matrix in the second iteration

	0	1	2	3	4	5	6	7	8	9	ND	Total
0	626	2	0	0	0	0	3	0	7	1	25	664
1	16	449	0	0	0	0	1	0	2	3	32	503
2	0	0	399	0	8	0	0	6	1	0	12	426
3	0	0	1	434	2	0	0	0	9	3	17	466
4	0	0	0	0	446	0	0	3	2	0	17	468
5	1	0	0	1	0	404	2	0	2	4	17	431
6	6	0	0	0	0	1	429	0	5	0	16	457
7	0	0	1	0	0	0	0	436	0	0	16	453
8	2	0	0	5	0	0	5	0	442	3	14	471
9	1	0	0	4	0	0	0	0	4	422	14	445
INS	29	12	6	4	19	7	8	2	45	17	-	149

INS – segment incorrectly recognized as a digit; ND – digit not detected

Iteration 2 – Human-driven model evaluation and adjustment: From Tables 2 and 3, it can be derived that the total number of segments that undergone classification in the attentive processing stage was reduced from 4969 in the first iteration to 4753 in the second. I.e., the number of processed segments decreased for 216 ($4969-4753$). This set of 216 omitted segments can be divided into two subsets. The first subset contains 172 segments that were incorrectly detected as digits in the first iteration, but correctly rejected in the second iteration. The second subset contains 44 segments that were correctly detected as digits in the first iteration, but not detected in the second iteration (cf. Table 4). The first subset is dominant, which implies that the modification of the segment filtering conditions in the first iteration resulted in a more balanced relationship between the number of segments incorrectly recognized as a digit, and the number of digit that were not detected.

In addition, the recognition accuracy at the digit level slightly decreased: from 94% in the first iteration to 93.79% in the second. However, the recognition accuracy at the number level increased from 67.02% to 72.46%. This is not contradictory – the number recognition accuracy is increased due to the fact that the number of segments that were incorrectly detected as digits was significantly decreased as a result of the modification of the segment filtering conditions. These conditions can be further optimized in subsequent iterations, but the first two described iterations suffice to illustrate the proposed approach.

Table 4

Filtered segments

Iterative learning loop	# segments in the attentive stage	Average # segments per image	St. dev.	INS	ND
1st iteration	4969	5.20	1.02	321	136
2nd iteration	4753	4.98	0.87	149	180
Abs. difference	216	-	-	172	44

INS – segment incorrectly recognized as a digit; ND – digit not detected

4 Evaluation and Discussion

The automatically calculated instantiation of parameters and the human-adjusted segment filtering conditions are evaluated on the *test corpus* containing 721 images containing only one rate (and the surrounding context). To avoid bias (e.g., training on the test data), the training corpus, described in Section 4, and the test corpus do not overlap. More precisely, it is not only that the training and test corpora do not include images of the same electricity meters, but they also do not include images of the same electricity meter types.

Table 5

Confusion matrix in the evaluation phase

	0	1	2	3	4	5	6	7	8	9	ND	Total
0	406	6	0	1	0	0	2	0	8	2	10	435
1	1	340	0	0	1	0	2	0	3	0	36	383
2	0	0	320	0	1	0	0	10	1	0	7	339
3	1	0	0	272	0	3	1	0	14	15	13	319
4	0	0	2	0	339	0	0	1	1	0	14	357
5	2	0	1	1	0	316	12	0	1	3	18	354

6	10	0	0	4	1	5	321	0	7	5	9	362
7	0	0	2	1	0	0	0	328	2	0	12	345
8	2	1	0	0	0	1	5	0	344	3	11	367
9	3	1	0	1	0	0	0	0	5	317	9	336
INS	8	40	7	9	10	6	24	15	57	10	-	186

INS – segment incorrectly recognized as a digit; ND – digit was not detected

The confusion matrix is given in Table 5. The obtained results are comparable to the results from the training phase. At the digit level, 91.83% digits are correctly recognized, 4.31% incorrectly recognized, and 3.86% not detected. At the number level, 61.03% images are completely recognized. The number of filtered segments per image is 5.05, with standard deviation of 0.95. For the obtained digit recognition rate (i.e., p_d is equal to 93.79% in the training phase, and 91.83% in the testing phase), the reported five-digit number recognition rate is close to the expected value (which, for the illustration purposes, can be approximated as p_d^5). We recall that this accuracy was obtained for images with significant noise and incompleteness, and emphasize, in addition, the following points.

(i) Reduced storage requirements. The recognition process rely only on a set of ten ground-truth feature vectors describing digits in set $\{0,1,\ldots,9\}$ (cf. set T in Eq. (15)). The recognition accuracy would increase with the number of the ground-truth feature vectors, but we wanted to reduce the storage requirements, in order to make this approach applicable for embedded devices such as mobile phones.

(ii) Generalizability and contextual information. Most aspects of the proposed approach to digit recognition are not domain-specific, including the pre-processing, feature extraction, feature vector comparison, segmentation, and segment classification. A small domain-specific part of the approach includes the ground-truth feature vectors, conceptualization of number as a horizontal pattern of digits (cf. Fig. 2(c)), and segment filtering (cf. point (ii) in Subsection 2.3.2). However, the domain-specific information just encodes the properties of the ground-truth templates, and are thus adaptable to other object recognition domains. The proposed approach does not utilize any additional contextual information that might improve the recognition accuracy (e.g., the expected number of digits per number, etc.). That was an intentional decision, in order to additionally support our statement on the generalizability of the approach.

(iii) Efficiency. Special attention was devoted to the efficiency of the prototype system. Searching through an image with a sliding window in order to conduct early selection of relevant image segments (cf. Subsection 2.3.1) is time consuming operation. Therefore, as already mentioned in Section 3.1, we decided to use only one predefined dimension of the sliding window, and the steps of the window along the axes were also predefined and constant. If we had applied more sliding windows of different dimensions and with different steps, it would have additionally increased the recognition accuracy. However, we decided to adopt a

trade-off between the accuracy and the efficiency of the system. The average processing time per image is 0.57 s (with standard deviation of 0.22 s) in the training phase, and 0.59 s (with standard deviation of 0.17 s) in the testing phase (measured on a standard personal computer).

(iv) Single-frame recognition. In the reported experiment, each electricity meter was represented by one single image. In a practical application of this technology (e.g., using an Android-based phone), multiple frames of an electricity meter would be captured and processed. Since each recognized digit is assigned a similarity score (cf. Eq. (19)), the captured frames can be evaluated, and the most appropriate candidate selected – which would additionally increase recognition accuracy.

Conclusions

This paper identified two separate but related contributions. First, we introduced a cognitively-inspired, non-connectionist approach to digit detection and recognition, in the presence of noise. Second, we proposed a novel approach to human-machine collaborative learning. The basic tenet of this approach is the refinement of a human designed software model, through the iterative learning loop, combining automatic data-driven parameter adjustment with human-driven model adjustment. This approach is demonstrated through a real-life study of automatic electricity meter reading in the presence of noise.

In the terminology of cognitive info-communications, automatic object recognition is referred to as an elementary cognitive capability [3, 4], in contrast to the higher level cognitive capabilities such as affective computing [37], human augmentation and health monitoring [16]. However, the proposed approach is relevant to the field of cognitive info-communications in two respects. One of the fundamental cognitive capabilities that remained under-investigated in this field is learning from small sets of prior experiences. Our approach to digit detection and recognition tends to meet, although only partially, this desideratum – its advantage is that it does not require significant training data, which is demonstrated in [18]. On the other hand, machine learning-based systems are usually developed in an extrinsic manner, i.e., a system is trained as a whole. The automatic adjustment of a large number of parameters leaves the practitioner out of the learning loop – it neither allows for human learnability in the training phase, nor does it provide the practitioner with insights into the performance of individual subsystems. In contrast to this, we proposed an approach to human-in-the-loop supervised learning. To illustrate human learnability, in Subsection 3.2, we discussed the idea that the iterative learning loop enables the practitioner to recognize the segment filtering, as critically important and extends understanding. More generally, the iterative learning loop is intended to make the process of software development more explanatory to a practitioner, by enabling them to intrinsically develop and evaluate individual subsystems, while keeping the advantages specific to supervised learning. In the dominant trend of ever more complex systems, based on black-box machine learning techniques, making the underlying computational models more human-interpretable, is an important requirement for computer-aided education in computer science.

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Movement Pattern Recognition in Physical Rehabilitation - Cognitive Motivation-based IT Method and Algorithms

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Abstract: In this paper, a solution is presented to support both existing and future movement rehabilitation applications. The presented method combines the advantages of human-computer interaction-based movement therapy, with the cognitive property of intelligent decision-making systems. With this solution, therapy could be fully adapted to the needs of the patients and conditions while maintaining a sense of success in them, thereby motivating them. In our modern digital age, the development of HCI interfaces walks together with the growth of users' needs. The available technologies have limitations, which can reduce the effectiveness of modern input devices, such as the Kinect sensor or any other similar sensors. In this article, multiple newly developed and modified methods are introduced with the aim to overcome these limitations. These methods can fully adapt the movement pattern recognition to the users' skills. The main goals are to apply this method in movement rehabilitation, where the supervisor, a therapist can personalize the rehabilitation exercises due to the Distance Vector-based Gesture Recognition (DVGR), Reference Distance-based Synchronous/Asynchronous Movement Recognition (RDSMR/RDAMR) and the Real-Time Adaptive Movement Pattern Classification (RAMPC) methods.

Keywords: cognitive infocommunication; rehabilitation exercises; motivation; Kinect sensor; adaptive interface controller; real-time gesture recognition and classification

1 Introduction

The area of cognitive infocommunication is ready to highlight the new capabilities of ICT in human-machine interactions. The special features of the systems that develop cognitive abilities also reveal the added indirect ability that can help the efficient operation and widespread use of systems based on human-machine interaction [1, 2].

Cognitive Infocommunication aims to create effective systems that are based on human perception, develop or return the cognitive ability of understanding and cognition to the user, all through models based on ICT engineering tools.

These include a number of studies that investigate the cognitive infocommunication environment, user experience, user experience [3], gesture recognition [4, 5] eye-tracking [6], BCIs [7, 8], VRs [9, 10], virtual lab [11, 12, 13], serious games, gamification [14] and other educational environments [15, 16]. These research findings are of great importance in the field of education, development, rehabilitation or even the industrial application of robotics.

One of the most important areas of application concerned is the field of healthcare information technology, including motion rehabilitation.

Unfortunately, stroke became one of the most frequent diseases of the modern day. All over the world and unfortunately also in Hungary, stroke is the most frequent cause of death and disabilities. Stroke has become the third-fifth cause of death: Every 20 deaths is caused by stroke, meaning that in America 140000 people are killed by stroke each year. Every year, 795000 people have a stroke and, out of them, 610000 is a new stroke victim. Stroke is not just the disease of the elderly, but unfortunately, in recent years it is increasingly affecting young people. The number of patients increases year by year. In Hungary, 42000 people suffer a stroke every year and 13000 people die of brain damage. Twenty-five percent of patients are younger than 60 years of age, but men have a stroke five years earlier than women on average and this has several social consequences [17]. Those who manage to survive the disease are also seriously threatened, as nearly 24 percent in the first year, and another 5 percent lose their lives in the second year. The stroke may affect one's life. According to statistical data, 48 percent of brain-to-asthma survivors suffer from half-side paralysis, but some degree of cognitive decline can be detected in more than 60 percent of cases. 22 percent of patients are impotent, many of whom are forced to a wheelchair. 24-53 percent of those who have undergone stroke are partially or completely dependent on others, 12-18 percent are aphasic (speech disorder) and 32 percent of them are depressed. This makes it necessary to involve devices of modern technology [18, 19].

Besides this, nowadays, the development of virtual reality (VR) applications is one of the most dynamically developing areas in the field of information technology. In the case of movement rehabilitation applications, modern sensors can be used as input devices. These sensors are of great importance, mainly those that are operating based on optical principles because of their convenient usability. [20, 21] The role of these IT solutions, serious games and frameworks that can be used in home environments is also significant in post-stroke rehabilitation. Many of these have been developed worldwide in the past years. Sadly, not many of them became popular as they did not achieve the hope people placed in them. The main cause of these unsuccessful rehabilitation projects was clear from experience gained in previous projects: the use of IT equipment that is difficult for patients, supporting people, nurses and also the loss of motivation of patients [22].

Depression of stroke patients often slows down the recovery process. Karaahmet et al. [23] examined the risk factors for the occurrence of this phenomenon. In their study, they found out that based on both post-stroke state and the improvement monitoring FIM test, that the improvement of patients with depression is significantly slower. Because of this and consequently, a lack of motivation appears as a generator and/or as a consequence of depression. The combined effect of these two can most likely cause the failure of rehabilitation [24, 25].

Rehabilitation can be made easier for patients as well, if rehabilitation exercises, gestures can be performed in an interesting modern environment. There are many computer-aided solutions already available that help with traditional therapy: the patient must have direct contact with the said computer (pressing keys, using a mouse) which can be a difficult task. Bruno and his colleagues have studied the possibilities of using commercial video games in rehabilitation in a study starting in 2015. Their study points out that based on 4728 related articles and abstracts of which 547 are focused on post-stroke rehabilitation and movement rehabilitation, video games could achieve similar results to conventional therapies [26, 27].

Motion tracking devices that have appeared in the last decade allow the user to not have physical contact with the control device, thus these devices make it easier to control difficult serious games. The use of devices with motion detection sensors could be useful in rehabilitation software. For example, the Leap Motion gesture sensor, the V1 (Xbox 360) and V2 (Xbox One) versions of the Kinect sensor and the Shimmer sensor as well. When using the Kinect sensor, various problems have arisen, for example, the difficulty of controlling as the device does not always perceive well or the gestures are inaccurately identified [28, 29]. The examination of these problems is mandatory because if there is no solution for them, then, unfortunately, it will be impossible to effectively use serious games or software for rehabilitation purposes [30, 31, 32]. Worthen et al. and Llorens et al. created multiple recommendations for exercise games (exergames) with the aim of stroke rehabilitation. With these recommendations, it is possible to deduce that the need for serious games exists for both therapists and patients. However, the requirements of their usability are not always fully met, therefore, the developments will not be applied to the caring protocols after the initial testing.

In 2017, Afyouni et al. presented a framework for stroke rehabilitation which gives a possible solution to the adaptive deficiencies stated by Worthen et al. and Llorens et al. In their framework, Afyouni et al. adapted the difficulty of the tasks during multiple cycles to the current state of the user [33].

However, the fact is that the exergames could not adapt to the needs of the patients if the correction values are pre-set or the therapist calibrated the application beforehand [34].

In this paper an adapting solution to the mentioned problem is presented: When using gesture recognition and evaluating the gestures in an application controlled with the Kinect sensor, the algorithm is capable to adapt to the state of the user in real-time.

The goal of the algorithm is to recognize gesture patterns during movement rehabilitation while classifying and evaluating the gesture patterns. This is an expectation regarding the basis of the therapy when using a software method.

One of the critical points of motion-based application control is the retrieval of motion descriptors from the sensor used as the input interface throughout the application. The present work of the authors was designed to extract, to process, analyze and to improve the motion data of the Microsoft Kinect sensor. The set of function sets provided by the sensor manufacturers to the developers allows the data to be accessed, but this alone is not enough for the developers and users of rehabilitation applications. There is too much uncertainty for the user. For example, the loss of connection during practice or a series of unsuccessful tries can demotivate the user.

2 Data Acquisition and Data Analysis

2.1 Data Acquisition

If the appropriate methodology presented in the next chapter is used, the loss of motivation can be avoided. More importantly, Kinect applications often appear in the field of movement rehabilitation, like the tools related to telemedicine systems. This means that the personal presence of the therapist is not required as telemonitoring does not necessarily take place in real-time, but nevertheless, it can provide the medical staff with therapeutic process tracking and evaluation of the results in a very human-like, graphical way.

Data logging is one of the basic tools that allow performing the tasks mentioned in the problem discussion. There are two versions of the sensors, the former Kinect for Xbox 360 sensor and the new Kinect for Xbox One.

In the data logger application, all or only the selected joint points are logged at the 30 fps sampling rate of the device, and every single repetitive movement can be described with 67 frames on average. Instead of the time-stamp provided by the device, the more efficiently used ratio number is stored during the skimming of motion descriptors, that are calculated from the time-stamp in milliseconds, based on the elapsed time from the start of the motion.

2.2 Data Conditioning and Analysis

By processing the stored data, a statistical analysis of movement can be provided and also it is possible to reconstruct from descriptive data.

The available data is noisy [28, 29] which is partly due to the random error on the data or the values calculated by the sensor instead of the measured value. These values are generally outliers that are largely different from the correct data. The measurement result, the subsequent processing, the accuracy of the gesture recognition can be influenced by the noise on the measured signal or the measurement error meaning that the signal must be filtered and made error-free before processing.

Of course, the goal is to be able to perform the processing in real-time, not just when processing the stored data. To do this, it is necessary to examine the running time of data clearing performance and to improve the accuracy of gesture recognition after the filtering.

Initially, several error correction algorithms were used, like 7th, 9th polynomials and Lagrange interpolation was also applied to the original data set.

2.2.1 Filtering with Lagrange Interpolation

If there is a set of N points on a Cartesian plane, there will always exist an N-1th order polynomial of the form

$$y = a_0 + a_1 x + a_2 x^2 + \dots + a_{n-1} x^{n-1} \tag{1}$$

which passes through all the points. Lagrange interpolation came up with a neat approach to finding this polynomial, which constructs a set of 'basis' polynomials which are zero at all specified points except for one, then scale and add them to match all control points.

When using Lagrange interpolation, the polynomial of the lowest possible number is used. Unfortunately, it is distorted at interval endpoints. The approximation method gave much worse data than the original measured data. To resolve this problem, another method was used which was a windowed interpolation technique. This interpolated through 10 measurement frame-windows by sliding the window until the full data set was processed. The comparison of the resulting data set and the original motion descriptors, then averaging the descriptor of the movement, gave a data set that was free from abnormal measurements and abnormal values.

Unfortunately, with the Lagrange interpolation approach, it took a very long time to process the input data as it was experienced, so a different polynomial fitting was used which gave very good results.

2.2.2 Filtering with Polyfit Function in Matlab

The data set was filtered using Matlab's built-in polyfit.m function in this case. When using the function, a predetermined degree of polynomials are available to be fitted. The 9th polynomial matching has the best results in our case.

It's syntax:

$$p = polyfit(x, y, n) \tag{2}$$

p returns the coefficients of the polynomial that fits best (examining the deviation of the least-squares differences) to the data of y.

$$p(x) = p_1x^n + p_2x^{n-1} + _{\dots} + p_nx + p_{n-1} \tag{3}$$

the results of this were used in the following parts.

Before doing the aforementioned filtering, it should be noted that the measurement data, like all measurements, can contain measurement errors that arise from environmental factors, such as the IR range of room-induced solar radiation can interfere with the sensor, or the frequency of the ignition transformer of the neon-tube lighting in the room can cause sensory disturbance. Changing the light conditions in the room used for measurement may impair the stability of the sensing.

These errors should be separated from the faults caused by the uncertainty of the movements of the user. These faults can be considered as errors or as faulty gestures from the point of view of the therapy.

The user's gesture can always be matched to a predefined gesture pattern. However, if it contains data that is significantly different from the sample to the extent that the gesture descriptor cannot be transformed near the sample descriptive values by simple filtering, it may be a defective gesture and not a defective descriptor resulting from the measurement.

2.2.3 Constructing the Error-Free Result Matrix

After calculating the polynomial data for the new curve, the resulting matrix was compared with the matrix containing the original data set of measurements at the same index locations. The difference was formed for each index and that was stored in $\mathbf{t_k}$ variables.

$$t_k = |m_k - y_k| \tag{4}$$

The mean distance **a** has been calculated:

$$\mathrm{a} = \frac{\sum_{k=1}^{n} \mathrm{t_k}}{\mathrm{k}} \tag{5}$$

As the next step, the data set containing the original measurement data set and the polynomial curve data was re-examined in pairs.

In the movement descriptor matrices the absolute value of the deviation of the values at the same index positions has been compared with the average deviation previously calculated. If this deviation was smaller than the calculated average deviation, then the original measurement data was considered good and remained in place. If it was higher than average, then the original data was considered and replaced with the replacement polynomial at the given position in the matrix with the following formula:

$$u_k = \begin{cases} if\ t_k < a\ then\ m_k \\ if\ t_k > a\ \ then\ y_k \end{cases} \tag{6}$$

The next section introduces the algorithms that were developed to improve the effectiveness and accuracy of pattern recognition.

2.3 Developed Movement Pattern Recognition and Classification Methods

2.3.1 Reconstruction of Movement Patterns/Gestures

In virtual and augmented reality applications, the most important for the human viewer is to see how deeply they can experience the effects of the perceived environment.

As already mentioned in the earlier sections, the optical sensors are popular with movement rehabilitation applications. In this study, the main focus was on the Kinect sensor.

The Microsoft Kinect sensor uses a built-in infrared depth emitter and camera, while it also uses a four-microphone array to detect the location of the user inside a closed space. The sensor works with a randomized decision forest. In addition, it uses the mean-shift clustering algorithm to determine which pixel belongs to which body part.

There are many cases in the physical rehabilitation process where certain serious game elements are incorporated to maintain motivation. Similar or repetitive gestures can be used to practice or to control a game.

Due to sensory error, movement recognition is often not eligible as the game could think that the gesture is incorrect. This results in the loss of motivation of the patient/player. The possibilities for more precise recognition of gestures will be introduced in the following chapter.

Two different methods for recognizing movement patterns are presented in this paper. Both of these methods can be applied in the time-dependent or time-independent mode for movement (gesture) recognition. The methods are reference-based methods, one of them is a reference-based time dependent and time independent distance vector differentiation:

Distance Vector Based Gesture Recognition (DVGR) method, while the other is based on a fixed-distance correlation of joints: ***Reference Distance Based Synchronous/Asynchronous Movement Recognition (RDSMR/RDAMR) methods.***

2.3.2 Reference-based Recognition and Identification of Movement Patterns

The two methods in general:

A gesture descriptor base functions as a basis for analysis for both mentioned gesture pattern processing methods. In both cases, the reference movement patterns are gathered beforehand, then during the processing and the recognition phases, the algorithm compares the actual movement pattern data descriptors to the base data in real-time.

Gesture analysis:

Analyzing gestures is a complex sequence. Its main functions are that it analyzes the gestures of a human, and decides which movement it is [35, 36].

The problem consists of multiple layers and is a difficult task. The primary problem is recognizing a human or shape on the picture. The previous methods could only recognize shapes in colored, one-dimensional pictures or in monochrome ones.

Its sequence is the following:

- The first step is determining the background and saving it as a starting basis.
- After determining the background, in the second step, the algorithm watches whether change happens in the picture. The simplest method was to compare the original and the newly transformed, black and white transformed new picture: If there are differences, then the pixels differ in the image.
- During the third step, the difference and the shape in the picture are determined. The usable technique is, e.g. a circle delimit method, where the deviation is delimited into a circle with a polygon and by analyzing this polygon the shape is defined

Defining the shape in itself is not enough for gesture pattern recognition. Other tasks include recognizing the gesture and its tracking. For doing such tasks, methods will be presented in the next sections. The basis of both methods is that it tries to recognize a saved gesture pattern which was gathered beforehand by using real-time data from the user. The user who does the movement sees a video during the gesture and has to follow it as precisely as possible. To understand and to recognize the gesture pattern, the identification of the user is not essential, only the skeleton data provided by the Kinect sensor is used instead of the picture data.

In these types of movement recognition, after the required movement pattern identification, the therapist teaches the reference motions, teaches the exercises to the algorithm - in other words records the references inside the application. In this reference movement recording state, the video file has to be stored and of course, the movement descriptors are stored together with the records. During these types of movement recognition, several different gestures and movement samples are stored in the application.

The job of the patients is to complete the tasks prescribed for practice as accurately as possible.

Movement detection with the Kinect sensor takes place in real-time in a three-dimensional space using *x, y, z* coordinates measured in meters away from the device. A simple gesture is about 60-70 frames on average, but depending on the complexity of the given gesture, the number of frames may be more. The essence of gesture recognition is that the processor continuously compares the coordinate triplets describing the movement of the patient to all enabled reference gestures in each frame.

The job of the application is to monitor which of the references has found a match with which frame/sequence and give feedback to the user.

However, in the early stages of rehabilitation, the patient's movement coordination is so weak that his gestures are mostly incorrect. In these cases, the recognizing software does not evaluate the gestures and does not give feedback to the user to avoid demotivation.

Expectations from the gesture processing methods (Fig. 1):

The methods, algorithms of gesture pattern analysis have to fit the following minimal expectations:

- It should be used when dealing with the practice of gestures that are not defined beforehand, meaning the application should accept more than one gesture including ones that are personalized or made by the users.
- Real-time feedback: During practice, the application has to give real-time feedback after each repetition. The feedback has to consist of movement acceptation or refusal. Also, this feedback must not slow the processing application.

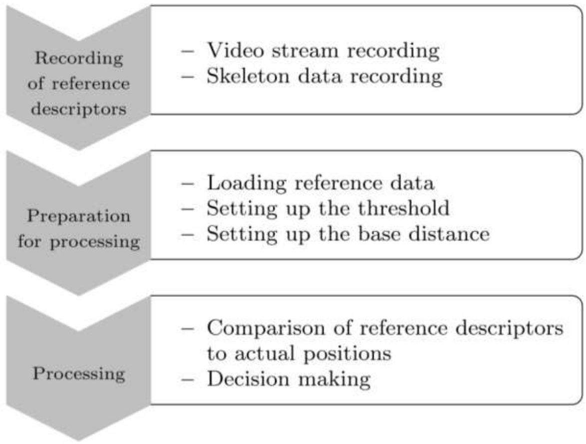

Figure 1
General method to process movement descriptors

2.3.3 DSMR/RDAMR - Reference Distance-based Synchronous / Asynchronous Movement Recognition Method

The other method of movement detection is synchronous/ asynchronous analysis, which is also based on a reference gesture base. However, in this case, the coordinates describing the movement of the user are calculated in a way that takes the base shift into account. The base shift characterizes the current position of the user relative to the reference movement when it was registered, in other words, it assumes a basic distance as a constant (Fig. 2). During gesture identification, the algorithm monitors the distance between the joint points of the skeleton, corrected by the base distance constant which determines which reference pattern can be applied with the highest precision.

In the case of synchronous analysis, with the time elapsed between successive frames of the movement pattern, the speed of the gesture could be calculated. In the initial rehabilitation phase, this expectation of the patients is too much. Therefore, the other method, the asynchronous analysis is used by this application, meaning that it only takes the coordinate triplets into account which can be found in each movement descriptor frame. The elapsed time is not taken into account which means that the speed of the exercises does not affect the qualification of the gesture.

In serious games, similar to movement pattern exercises, simple, often-repeated actions are performed by patients to control the game. Successful game controlling (or successful practice) is a requirement to allow the sensor to identify the gestures in real-time and to allow the software to adapt to the current abilities of the patients. This way, they are motivated for further exercise.

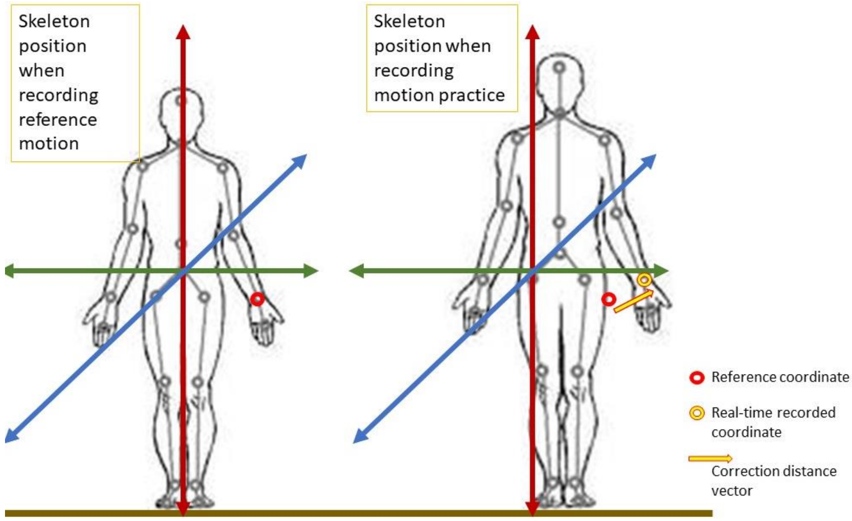

Figure 2
Baseline distance model

The application monitors which of the references has found a match with which frame-sequence. It returns feedback after identifying the matching gesture. This is an important part of the process, many previous studies have shown that positive feedback motivates patients.

However, in the early stages of rehabilitation, the patient's movement coordination is so weak that his gestures are mostly incorrect. In these cases, the recognizing software does not evaluate the gestures and does not give feedback to the user to avoid demotivation.

The formal diagram of RDSMR/RDAMR methods can be seen in Figure 3.

The main difference between asynchronous and synchronous movement recognition method is the speed of the analyzed movement.

The main advantage of the proposed method that it can be used in time-independent mode, because the evaluation process calculates only with the sequence of movement descriptors, but the result does not depend on the elapsed time between two consecutive descriptors.

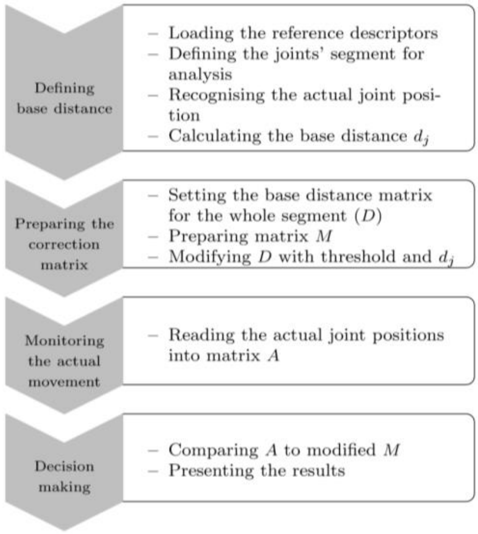

Figure 3
Baseline distance method

2.3.4 DVGR – Distance Vector-based Gesture Recognition Method

During the research, the Kinect v1 sensor has been used which can track 20 joints in a skeleton.

The problem is that when the user stands at a different distance from the sensor than when recording the reference movement, the sensor sees different X, Y, Z coordinate positions of the joints. This could lead to problems when processing data.

This could be solved by using the distance vectors between two joints. These vectors could provide the basis of comparison in the future.

Aside from the assigned joints from the side of the body, another joint is selected which has a pseudo-static attribute regarding movement, which is called a base joint. This base joint is compared with a distance vector to the position-triplets of other, analyzed joints when using the DVGR method. For example, when analyzing a hand movement, the left-hand descriptors are made by subtracting the analyzed wrist and elbow coordinates from the coordinates of the left shoulder. These distance vectors provide a momentary position.

Figure 4 presents the formal working progress of the ***DVGR -Distance Vector Based Gesture Recognition*** method.

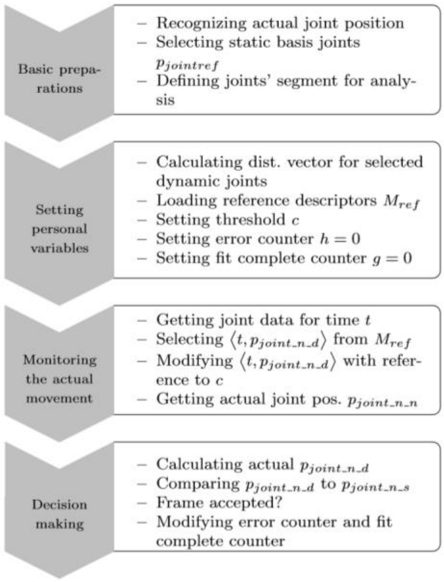

Figure 4

Distance Vector-based Gesture Recognition method

Notations:

- t is the actual loaded sample/measured time index,
- s means recorded reference (sample) data,
- a means the actual measured position data,
- joint means the selected joint from the analyzed joints,
- n is the number of joints in the selected segment,
- x, y, z are the Cartesian coordinates for each joint,
- $dist_{\{required\}}$ length of distance vector in the sample data set,
- $dist_{\{real\}}$ is the length of distance vector for the real joint position
- Static reference joint is $p_{\{joint\_ref\}(x\_\{ref\}, y\_\{ref\}, z\_\{ref\})}$, measured position
- The actual measured joint position is $p_{\{joint\_n\}(xt, yt, zt)\}}$
- c is a threshold variable, which gives the possibility to personalize the method, input variable for the algorithm
- h is a counter for not fitting frames
- g is a counter for fitting frames

2.4 Gesture Classification – Real-Time Adaptive Movement Pattern Classification (RAMPC) Method

The most important information for classification is whether the gesture for the given control was appropriate, acceptable or not. Successful classification required an additional method, its principle is shown in Figure 5.

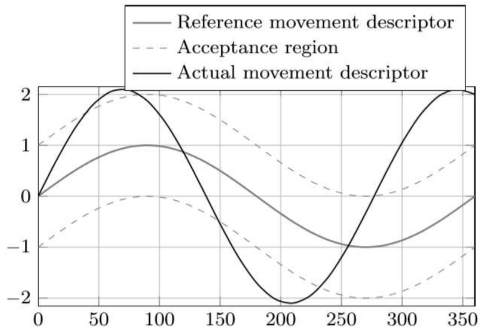

Figure 5
Classification

The classification works with a reference movement descriptor.

The algorithm allows for using multiple saved reference movement descriptors. Each different gesture descriptor can be found in a personal, holding vector. If the hand of the user is in the correct starting position in the correct time/frame (few tenths of seconds), also counting the threshold, then the application increases the index of the vector. However, the application can increment the index in multiple vectors as multiple gestures can start from the same position. If no index has been increased in the frame, then the algorithm increases the number of errors. If the number of errors reaches a predetermined value, then every index will be set to zero and the gesture recognition will start from the beginning.

The counter can be modified in an inverse direction as well. This happens when the user correctly does the movement in the frame and the application counts that as a correct frame by adding it to its respective vector as each vector has its own correct frame counter. Naturally, the done movements cannot be fully the same as they were saved beforehand. Therefore, if the user fails the last 10-20 indices of the movements (depends on the threshold value), but their error number is below a predetermined value, then the gesture is accepted.

The user can add gestures to the application, but the gestures do not have to be done in the saved order. Every sequence can be accepted and the movements can not only be done once but multiple times.

For example, look at a circular hand movement. The 3D domain of the reference movement is expanded: both in positive and in negative directions. A broader tolerance threshold is defined around the circular movement from the outside and from the inside. This range will be the acceptance range later on and serves as a basis for classification. The other standpoint which must correspond to the motion-descriptive coordinate set is that the number of motion-describing frames for a movement pattern averages 60-70 frames. Taking the faulty measurements and deviations due to incorrect movements of the user into account, the descriptive frames must be within the acceptance range in a predetermined amount of 50\% by default. During therapy and exercises, the goal is to have as many coordinates of the gesture as possible in this acceptance range. If the coordinate triplet of the frame is outside, then it cannot be considered part of the expected gesture. Like the previous sections, there are also reference gestures, reference descriptors in this case, but they are not stored on the basis of an external sample. Instead, they are calculated from the average of the first few movements of the given patient and are there completely adaptive to the current user and their capabilities.

Classification can be done with any periodically repeating gesture. They do not have to necessarily be circular movements.

This classification algorithm ensures that the qualification, acceptance or rejection of the movements is always adapted to the needs of the patients.

The main algorithmic steps of the classifications can be seen in Fig. 6.

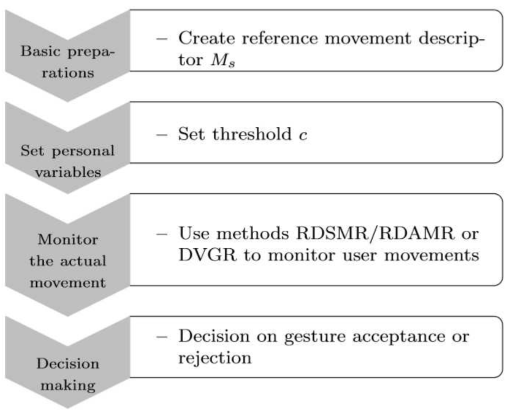

Figure 6
Basic classification method

A question arises: is the symmetric acceptance domain useful, or different ranges should be defined for different directions? The next section gives proof of this because by using the adaptive acceptance domain for every classification step that could be adapted to the user's (patient's) own capabilities, it will automatically adapt to the progression of the user.

2.5 Adaptive Acceptance Domain

During classification, one of the most important aspects is that the application should work in real-time, observe the movement of the user and evaluate them with the shortest delay and response time possible. Following this approach, an adaptive control application has been developed to support applications using the Microsoft Kinect sensor in real-time and it uses the classification algorithm presented above. During its operation, it monitors the gestures of the user in real-time and compares the reference gestures generated from the first gestures. It also takes the acceptance range into account which in the present case is a distance of d meters in positive and negative directions, so its scale is always a symmetric interval of **2d.**

By default, if more than 50% of the frame of the gesture is within the range of ±d of the reference value, the gesture is accepted. Also, the therapist could increase or decrease the range of d to adjust to the rehabilitation program of the patient. The acceptance rate of 5% can also be increased or decreased, resulting in a fully customized therapy.

As with the simple recognition presented earlier, the users also receive positive feedback if the gesture is successful to motivate them to continue their practice.

The next session introduces a case study, where the authors performed a user test to give the proof of concept.

3 Experimental Results – Case Study

3.1 Record Movement Descriptors

To prove the initial condition, the first step is to record large amounts of data. This process required 15 people who performed different movements, gestures. The data were recorded on the basis of the practice of physiotherapists in stroke rehabilitation. All movements are a typical SRM (Single Repetitive Movement) movement. SRM means that in rehabilitation, all patients have to repeat the movements 15-50 times, sometimes even 100 times or have to repeat them continuously for 2-5 minutes.

With the simultaneous launch of the two sensors, data logging software allows motion-based files to be recorded in text file format. The main advantage of the recorded files is that these are easy to process.

The scenario of data capturing:

Data capturing consists of two parts. In the first one, six different gesture exercises have to be done during the synchronous operation of both sensors. These exercises mainly concentrate on upper limb movements. The tester was put 180 cm away from the sensors as that was the distance which was the most appropriate for the authors.

Establishing the exercises:

- 1st measurement: The tester, with their palms toward the sensor at shoulder height, starts to move both their hands in circular motion ten times.
- 2nd measurement: Next, the hands have to be extended to the side, then retracted ten times while the palms are facing the sensor.
- 3rd measurement: At the start, the arms are at ease next to the body. Then, they have to be raised to shoulder height, extending sideways and in the end, going back to the starting position. The repetition number is also ten.
- 4th measurement: The arms start in the same position as in the 3rd measurement. Then, they have to be raised over the head while they are extended sideways, repeating ten times.
- 5th measurement: At the start, the legs of the user are closed. First, the right, then the left leg has to be raised sideways in 45-60 degrees, repeating five times.
- 6-7th measurements: The tester sits on a chair, where their arms are raised to shoulder height and their palms are facing the sensor. The tester raises both their arms above their head, then back down, repeating five times. The arms only move up or down as sideways movements are prohibited. During this, both their legs are raised, extended then put down to the ground, repeating five times.

Recorded files contain a matrix of coordinate-triplets: in every row, the matrix starts with a time-stamp, and the joints' coordinates follow. For each cycle, there are 60 movement descriptors stored.

After recording movement data, it was necessary to analyze and decide, if filtering and smoothing of data were needed or not.

During processing, the data set of the measurement data (i.e. the patient movement) has been examined. The first purpose of the study was to find out whether an error-correcting algorithm that supports movement detection in the later phase of processing would be needed. The second purpose was to find out if that algorithm would allow more accuracy during detection.

3.2 Filtering and/or Polynomial Fitting for an Error-Free Data Set

By comparing the original set of data and the error-free data set, the modified index location can be determined which also reveals which original data was incorrect.

After the data smoothing, the cycle searching process was performed on the data. It should be considered, that the found difference between the repetitions on the original data and on the smoothed data was only 5-15%. Meaning that real-time processing cannot be used because of the long processing time, but the result of the original data set is not usable if every 5th movement was recognized as a failed movement. This result indicates to use an adaptive acceptance domain for classifying the recorded movements.

3.3 Reconstruction of Movement Patterns

After the measurement data is input into the Matlab/Scilab/Excel environment, where the reconstruction of the movement pattern can be done 1D, 2D and 3D while taking the elapsed time into account.

During the reconstruction, the viewer receives a real picture of the nature of the movements performed during the therapeutic practice, the number of repetitions, and the graphical display. For example, deviation from a reference motion pattern.

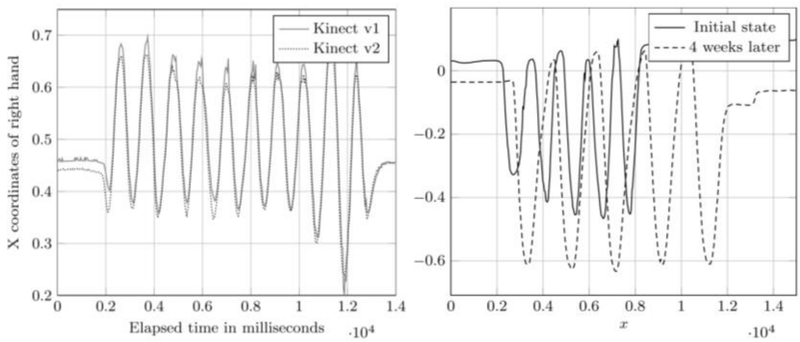

Figure 7 a,b

Circular movement with the Kinect v1 and v2 sensors, X coordinates and elapsed time; b) Leg raises in different periods of rehabilitation, X coordinates and the elapsed time

As can be seen in the reconstruction figures Figure 7a and Figure 7b, it can be decided by the therapist looking at the measurement data set that whether there is a progress in the movement rehabilitation of the patient or not.

3.4 Classification and Transform Movement Data into the Adaptive Acceptance Domain

To keep the motivation for further exercises, it is necessary to ensure the patient's continuous successful experience, a movement assessment that adapts to their special needs. The different acceptance domains can be seen in Figures 8-9.

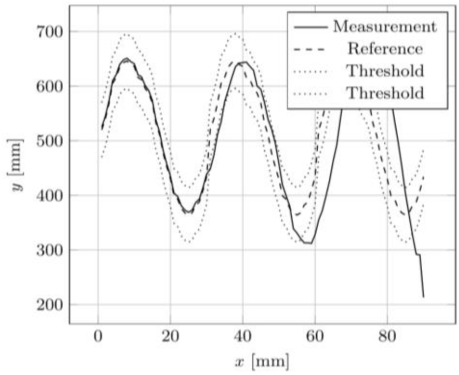

Figure 8

The acceptance domain is ±50 mm over the reference movement descriptors

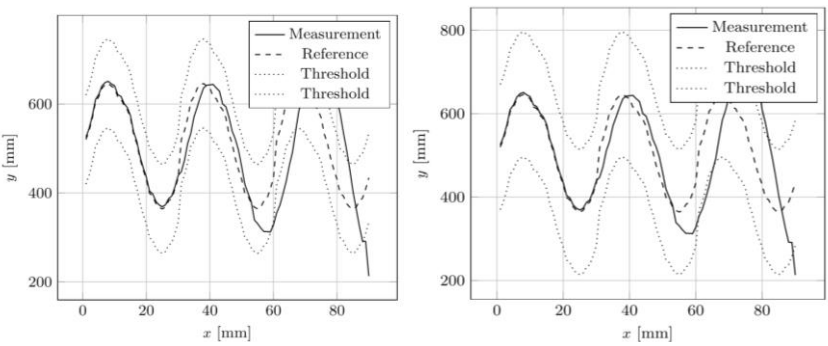

Figure 9 a,b

a) The acceptance domain is ±100 mm over the reference movement descriptors; b) The acceptance domain is ±150 mm over the reference movement descriptors

As can be seen in Figure 9b, where the acceptance domain size was ±150 mm over the reference movement and the acceptance ratio was 50% of contained frames, the first whole movement cycle was fitted in 96% and was accepted. The second movement cycle was fitted in 53% and also was accepted, but the third movement cycle was fitted in 37% and it was refused.

If the therapist chooses other acceptance rate, such as, 60%, it means, that the second cycle could be refused because of the more strict classification parameter. This method can be applied in the developing state of the patients.

In Figure 9, the different acceptance range can be seen. In this situation the acceptance range is ±100 mm over the reference movement, the acceptance ratio is 50%. As is presented in Figure 9, the third movement cycle was refused on a 33% fitting ratio, as in the previous sample, but using ±50 mm acceptance range over the reference movement Figure 8, it will be refused on a 16% fitting ratio.

These samples show that the size of the acceptance domain, together with the fitting ratio, on every movement cycle can give a solution to accept purer and unstable movements, when the user could not make more precise gestures, and it could result higher motivation, more initiative on the part of the user to continue the exercises.

3.5 Discussion of the Results

After capturing the motion data, the authors investigated whether the time needed to produce the corrected data set was suitable for real-time processing or not, as well as whether there was a significant difference after correction in the number of recognized, correctly identified cycles or not. Based on the results, the Lagrange interpolation data filter takes too much time, it is not suitable for real-time movement detection. The polynomial fitting method allows the data to be filtered during runtime but does not bring significant improvements to the recognized movement cycles. This means that it is not advisable to perform pre-filtering and data correction before using the movement detection algorithm.

During recognizing movement patterns, the best result is achieved by the distance vector-based pattern matching which is also the primary test method for classification using the data-accepting range.

Finally, it can be concluded that the acceptance range-based adaptive movement classification for Kinect can be used in real-time. This method provides effective support for adapting to the patient's current capabilities throughout the rehabilitation process, despite the coordination constraints of motion while always ensuring successful software utilization, maintaining motivation and preserving the gaming experience which is one of the pillars of effective rehabilitation.

Conclusions

The analysis of motion data, pattern recognition, reconstruction and visualization of motion patterns are the basic questions of the personalization of movement rehabilitation applications, which indirectly support the effective use of IT tools.

Inadequate interaction tools, especially in mobility rehabilitation applications endanger the long-term use of the applications as the user becomes unmotivated and their interest is lost while also endangering the positive outcomes and efficacy of the treatments.

The author's experience gained in the international and national projects confirms that the continuous success and motivation of the user is an important condition for successful treatment.

There is a need to develop a method that provides a sense of success for the user while using the rehabilitation applications with the Kinect sensor in a way that gestures are processed and categorized in real-time and adapted to the special needs of the user.

The motion data extracted from the Kinect sensor contains estimated values when the sensor loses contact with the user and also contains misaligned coordinate data. In the course of the investigations, the result was that the preliminary error correction of the data is not necessary during the subsequent processing: Errors during the recognition and classification of the gestures do not result in significant deviations in negative and in positive directions.

The studies carried out showed that in the case of the Kinect sensor, the different processing methods of the motion data associated with the 'skeleton' showed different results in the recognition of the gestures.

Methods that were developed simultaneously with the research, the DVGR and RDSMR/RDAMR methods can be used to identify users' therapeutic gestures used in rehabilitation applications in real-time with high accuracy in the application control.

The Real-Time Acceptance Range-based Adaptive Movement Pattern Model Classification (RAMPC) supports Kinect sensor's control of motion-recovery gaming applications, which according to the user's needs, defines – based on relative reference base generation – controllable parameters for a dynamic acceptance domain to accept user gestures. This method makes Kinect sensory-driven motion rehabilitation applications applicable at every stage of the therapy, so it does not cause any unsuccessful movements during exercise, does not cause a demotivating effect in a high degree of motion limitation, and therefore, is likely to maintain a constant motivation for the user.

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An Architectural Approach to Cognitive Information Systems

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Abstract: The fast changes in information technology and business needs have led to the evolution and development of Cognitive Information Systems (CIS). There have been few pieces of research on the general model for the analysis and design of CIS. This paper attempts to create a design scheme for incorporating the various models for CISs and Understanding-based management systems (UBMSS). The components that have been examined, create elements of CIS analysis and design, however, they were not described as modeling elements and not described as enabling tools needed to create a consistent and integrated system. The most significant components for modeling are: semi-structured documents, business processes, constituents of knowledge management, the enterprise and the information architecture, including self-directing software components - Artificial Intelligence (AI) - that yield functions. For CIS modeling, the above-mentioned elements were combined into a unified framework, that follows the object-oriented paradigm and architecture approach. The aim of the research is to describe a framework that presents an overarching model and assists our understanding of the properties of CIS and UBMSS, allowing the formulation of a practical development method for CIS and cognitive management systems.

Keywords: architecture of cognitive systems; UBMSS; management supporting systems; zachman architecture

1 Introduction

In the past, there was a profound evolution in the use of information technology within companies. Information Systems (IS) architectures have been developed out to depict and to maintain the several layers, tiers and components of the architecture. IS architecture synthesizes facets of systems by defining views and viewpoints that can be realized by various models described in various methodologies for information systems analysis and design. The theory of Cognitive Infocommunications by Baranyi et al. [2] [3] [4] has pointed to various aspects of IS, human-computer interactions, and gives a newly available approach of IS. The concept of Cognitive Information Systems can be perceived as an interdisciplinary area of Information Systems and Cognitive Science. Modeling, analyzing, and designing information systems by the most modern approaches provide opportunities for the application of architectural and design methodologies that unite the development methods of systems and theories of Cognitive Science [2]. We perceive the architecture of information systems within companies according to Zachman [31] and the TOGAF approaches [16]. The evolution of technology in the realm of information systems can be seized by the notion of Data Science and semantics. There is a classification of cognitive information systems as understanding based cognitive systems (UBCCS, Understanding Based Cognitive Categorization Systems) [22]. Within that categorization, there are enterprises and management related systems as UBDSS (Understanding Based Decision Support Systems), UBMSS (Understanding Based Management Support Systems). The case studies referenced publications in the form of a proposal for developing systems investigate single, double and multifactor analysis approaches that use Net Present Value (NPV), Internal Rate of Return (IRR), and discount rate [22]. The presented approaches are based on formal languages, that describe building blocks for cognitive analysis that can be considered as semantic analysis that is based on logical predicates in the form of rules and concepts. The toolset that is utilized in this approach is grounded in finite state machines, automaton and theories of formal languages to deduce the assessment of the formalized situation [11]. In addition to the systems with single-factor analysis (IRR, NPV), there is a description of systems with dual and multi-factor analysis. All the proposed systems pursue the same methods, i.e. defining a grammar, capturing the essential concepts in terminal and non-terminal symbols within the grammar, and predicates of decision making are formulated as rewriting rules of the grammar initiating state transitions within the realm of analysis. [22]. The basic version of the UBMSS have been refined further into several sub-classes, namely UBMLRSS (understanding based management liquidity ratios support systems), UBMPRSS (understanding based management profitability ratios support systems), UBMARSS (understanding based management activity ratios support systems), UBMFLRSS (understanding based management financial leverage ratios support systems) [23]. All of them use balance sheet and profit and loss data, out of extracts from the general ledger and data from various sub-systems. This data set is used in creating Business Case, Strategic Business Plan and in credit requests from banks. These data play an important role in the life of a company and its future, these data serve as a basis for further decision making, therefore the availability and appropriate elaboration of data generates and improve the value of the enterprise.

Molnár et al. [20] were to elaborate a model framework for an Information System considering the various technological and software architectural solution. The current research attempt to elaborate on a modeling framework for CIS considering the various architectural and technological components and solutions. The proposed model shows how the earlier created methodologies and methods for analysis, design, implementation, and management can be used to construct

CIS in a framework to combine various perspectives and aspects to create a comprehensive model including the relevant aspects of CIS, based on the model a methodology and related methods.

2 What Makes CIS & what is UBMSS?

CIS according to Hurwitz: "Three important concepts help make a system cognitive: contextual insight from the model, hypothesis generation (a proposed explanation of a phenomenon), and continuous learning from data across time"[13]. From the other viewpoint, Wang postulates that a "denotation mathematical" approach is required that own structures, tools, and methods beyond the traditional mathematical logic [28]. Ogiela collected areas of application of informatics and information technology where cognitive information processing techniques are incorporated into various systems [22]. Extending the definition based on the examined publications, the ideal CISs, other than the predefined details which are, contextual insight from the model, hypothesis generation (a proposed explanation of a phenomenon), and continuous learning from data across time, should impact the carbon agent cognition, in a positive way, improving it, leveraging the synergy originated from the interactions between silicon and carbon agent. This synergy generated leverage expressed via cognitive resonance. The cognitive resonance orienting the entire process to the automated data understanding meanwhile extracting the semantic information, which supports the interpretation of the understanding [21]. The cognitive resonance is a synergy with a positive impact generated by HCI (Human-Computer Interaction) that embeds the Cognitive Infocommunication into itself as a tool and as a channel. Utilizing the biological analogy, the Cognitive Infocommunication ensures that the information as a stimulus arrives at the receptor that operates as a sensor, or as a sensory organ. It is capable to exert an impact on the system and the system reacts through responses. The stimulus is either information or raw data that are transmitted, between the parties playing roles in the action of the infocommunication that improve the cognizance of both sides during HCI. The data stream that is realized by Infocommunication, can be represented as a bidirectional channel. The cognitive resonance supports the sensed data extraction and the semantic understanding. Both parties via HCI might become the initiator of the stimulus or might be a receptor or a sensor, at the same time.

According to Vincente Raja, ecological psychologists have developed concepts of dynamic systems theory (DST) as a preferred explanatory tool for the agent-environment interactions [26]. Based on our concept, it shows some similarities to the previously described acts of Cognitive Infocommunication, to its roles, as well as the cognitive resonance, however, this needs further research to analyze the similarities and discrepancies.

In line with our understanding described above CIS cannot exist without the capability of adding value, improving processes of understanding. The concept of cognitive resonance is one of the attempts that try to make sense of the modeling activities in the most recent world of data analytics that uses tools out of data science. According to Lemieux as society moves into the era of cognitive systems in which more decisions are by intelligent machines or humans working in collaboration with intelligent machines, it becomes increasingly important to consider how we will build accountability for decision-making into such systems [18]. The information architecture that can provide an opportunity for creating a framework to describe the information exchange between the human parties along with her/his supporting silicon agent and cognitive information systems can be grounded in Enterprise Architecture, and LIDA [16] [31], [17]-[8]. The advantage of the LIDA model as architecture is that it focuses on the cognitive processes and their structure at both conceptual and computational levels [7].

3 UBMSS versus CIS in Light of Zachman Framework

Zachman's framework contains the various business perspectives as different viewpoints of stakeholders. The perspectives identify the layers of the architecture. The aspects embody the distinctive modeling approaches. Expanding the Zachman framework [31] with cognitive elements supports cognitive architecture, therefore improve the system under consideration up to the cognitive level.

The contextual perspective's basic requirement is to be able to identify the goal of the system to be developed. In case of UBMLRSS (understanding based management liquidity ratios support systems), UBMPRSS (understanding based management profitability ratios support systems), UBMARSS (understanding based management activity ratios support systems), and UBMFLRSS (understanding based management financial leverage ratios support systems) the goal is the support of management in issues that are related to ratio calculation.

In the conceptual layer, the concepts, which appear within the contextual layer are fragmented due to partial ratio analyses in the financial environment, do not fulfill its goals on the business level, therefore, do not fits into the enterprise model. In practice, the analyses will not bring any added value, which is essential in the case of a cognitive system. Therefore, in this case, the correct conceptual perspective should be a system for ratio analysis that brings additional added value along with business intelligence, via cognitive resonance, that would be covered in detail by the various aspects.

Table 1

A mapping semantically between Zachman architecture and CIS's components

Aspects / Perspectives	*what*	*how*	*where*	*who*	*when*	*why*	
Contextual	Fact, business data / for analyzes with cognitive resonance	Cognitive Business Service with the synergy of the cognitive resonance	Chain of Business Process, Workflow	Business entity, function	Chain of Business Process, Workflow	Business goal	Scope
Conceptual	Underlying Conceptual data model / Data Leak structured and unstructured	Cognitive Service with added value originated by the cognitive resonance	Service composition with cognitive business intelligence	Actor, Role	Business Process Model	Business Objective	Enterprise Model
Logical	Class hierarchy, Logical Data Model [A] structured, semi structured and unstructured	Cognitive Service Component	Hierarchy of Cognitive Service Component	User role, service component	BPEL, BPMN, Orchestration	Business Rule	System Model
Physical	Object hierarchy, Data model	Cognitive Service Component	Hierarchy of Cognitive Service Component	Component, Object	Choreography	Rule Design	Technical Model
Detail	Data in DBMS	Cognitive Service Component	Hierarchy of Cognitive Service Component	Component, Object	Choreography, Security architecture	Rule specification	Components
Functioning Enterprise	Data	Function	Network	Organization	Schedule	Strategy	

The idea of CIS is to make available a Cognitive Information System embedded into business and the organizational environment through Web technology. For that reason, the model and design methodology should consider the socio-technological environment, moreover, the Web and the software engineering approaches to enhance the system with modern data analytical solutions and amend its functionality, namely:

- Computing on the Internet, to ensure the system availability supporting business continuity
- Distributed transaction processing
- Knowledge management
- Set up various KPI's (Key Performance Indicators) in line with the business process
- Set up various clip levels - build in automatized approval levels, to support the management decision with relevancy related to the decision-making process and simplify the process itself

- Identify drivers and value-added models - for example, Du Pont Modell - into the integrated ratio analyses - that would ensure a business intelligence and deeper explanation and understanding of the analysis
- Develop additional aggregated analyses - simplified format - to support management with accelerated process flow, and with accelerated automatized, semi-automatized decision
- Add additional information to the analyses related to the industry - industrial risk identifier - industrial beta (P)
- Build-in data visualization to support the understanding of the analyses
- Capture a record of reasoning and decision-making for further decision making

Consider intranets and extranets and integrations, to support data availability and business continuity, knowledge sharing, data integrity and orchestration:

- Add additional information from internal sources, DB's (databases), etc.- payment history, order history, information from ERP and/or CRM, etc.

XML / HTML documents either as Web pages or information resources, - adding additional external information from international and/or local credit rating organizations - Moody's, Fitch etc.-, to ensure updated market information integrated into the analyses, improving quality of analyses:

- Database management systems and data warehouses, tracking, saving and in case of need sharing results
- Document management systems
- Enterprise Architecture, Service Oriented Architecture, Web services, micro-services
- Identify events-based triggers within the organization and inform cross functions via messaging
- Business processes analysis and management of the Web site - online business processing
- Business process analyses support with KPI's: customer satisfaction, cycle time, etc.
- Information Security: integrity, confidentiality, accuracy, availability, timeliness - information infrastructure
- Performance and scalability issues

On aspects level, to fulfill the CIS requirements related to the cognitive resonance, where the cognitive resonance is to be integrated into/between the two aspects, that would ensure the continuous improvement of the cognitive level of the information system.

The logical model to be built without fragmentation, the integration would ensure the appropriate level of cognitive resonance.

The physical and the detailed specification layers are to support the above layers according to the scope and the enterprise and system model.

As perceived by Molnár et al. [20] Enterprise IT Architecture as the suite of strategic and architectural disciplines that includes the Information, Business System, and Technical Architectures [20].

Business (systems) architecture - Defines the structure and content (information and function) of all business systems in the organization [20]. UBMSS Systems are currently lack of structure and content definition from that point of view, that might strongly question the capability for management support that is the partial scope of the system.

Information (or Data) Architecture - represents the main data types that support the business; furthermore, the structure (including interdependencies and relationships) of information required and in use by the organization [20]. The fragmented information architecture causes limited support, interdependencies and relationships within ratios are not visible, therefore the result of the analyses with UBMSS doesn't fulfill its scope.

Application Architecture - defines applications needed for data management and business support; the collection of relevant decisions about the organization (structure) of a software system, and the architectural style that guides this organization [20]. As the above reason decision support does not cover the management support requirement in case of ratio analyses, missing an integrated overview on results and reasons, the system is not able to predict based on the data analyzed, the cognitive resonance is missing, therefore the added value is missed.

4 Reality and Expectations Form CIS in the Enterprise Environment

Essential to make it clear that what is the expectation from CIS. There are various non-solved, or partially solved constraints on CIS, therefore the goal of CIS architecture must be clearly defined. Improvisation, new hypothesis generation, and testing were unrealistic expectations, thus those are still human capabilities. A human can observe and learn new knowledge from the environment, as it is the human capacity to interpret them appropriately. However, researchers formalizing unsolvable problems, try to find a solution with CIS / AI capability to answer and / or build a future CIS capable of solving problem without resource in a creative manner in an intuitive way with improvisation is currently not the reality, as CIS needs to leverage various heuristics and other assets and experiments to be able to solve the given problem [27]:

- Related to capabilities and abilities
- Impasse detection - to be able to evaluate the current situation versus capabilities and abilities [1]
- Domain transformation and problem restructuring - in plan task revision has formally examined the effects of changing the state, including the goal, and the operators [9] [10]
- Experimentation, learning form interaction with the world, considering exploration and reinforced learning [11] [25]
- Discovery detection - to be able to solve problems in case of unexpected events, with intelligent reasoning demonstrating autonomy. [27]
- Domain extension - to be able to know how and when to absorb new knowledge form the given domain [10]

Parts of the problems were solved, however, there aren't exist CIS capable to answer a complex challenge where all of the above -listed features are needed at the same time. CIS development more focused on specific tasks in specific domains, therefore the usability is limited and specific. Due to the above fragmentation, there is a need for orchestration of the already existing technics and solutions.

Considering a strategic decision that makes humans capable to build from a complex environment their observation - based anticipations into a decision - making process, transforming it as a potential result as an "expectation" in the outcome. This process teachable to CIS via cognitive resonance, via decision - making learning circle, to make CIS capable to support human strategic decision making [21]. However, the mentioned intuitivism and interpretable improvisation are originated by the carbon agent.

According to the above, there is no question yet regarding the statement of John Smith, Manager of Multimedia and Vision at IBM Research who mentioned related the creativity the following: "It's easy for AI to come up with something novel just randomly. But it's very hard to come up with something novel and unexpected and useful [14].

In the case of CIS architecture to be considered the level of complexity. Simple tasks do not need a complex solution, i.e. CIS. Building CIS with complex problem-solving capability may increase the architectural, programming and other CIS building - related challenges in an unrealistic manner. Aspects impacted by the previous problem are including related technics, time, expertise newly developed parts, financial and other resources and capabilities, where all of the elements are available and orchestrated in a well -functioned manner both on a holistic and functional level. Lack of the expected functionality determinates the holistic system approach negatively, therefore, one of the essential tools/assets in the orchestration the synergy supported by infocommunication.

5 Zachman Architecture & its Cognitive Elements

By Wang definition: “Cognitive Informatics (CI) is a transdisciplinary enquiry of cognitive and information sciences that investigates into the internal information processing mechanisms and processes of the brain and natural intelligence, and their engineering applications via an interdisciplinary approach” [30].

In the case of cognitive elements, the contextual insight derives from the model, hypothesis generation, and continuous learning through cognitive resonance via HCI (Human - Computer Interaction), then the human (carbon agent) indirectly modifies the model, generating enabling CIS to generate new hypotheses across the learning process. Therefore, the most significant features of CIS the ability of the HCI and the interaction generated resonance, that enables CIS to improve their cognitive level.

Wang defined a model to describe the context of systems within Cognitive Informatics. “The Information - Matter - Energy (IME) Model, building a bridge between the natural world (NW) where the physical, concrete world (PW) and the abstract or perceptive world (AW) connected to each other, where matter (M) and energy (E) model the NW meanwhile, information models the AW.” [30].

In this definition, the abstract and perceptive world is within the realm of human minds that is the subject of Cognitive Informatics through applying the formal methods of information processing.

Based on the above-definition, the role of the CIS within Wang’s model can be interpreted in three ways. On being aware that the content of an Information Systems that we consider as information consists of data and programs as a combined unit, therefore we consider the second learning cycle across HCI to be the basis of observation, due to the first circle did not necessarily impact nor the NW, AW and CIS. Interpretations:

1. CIS equivalent of AW
2. CIS wedged entity between NW and AW
3. CIS a separated entity, therefore out form NW and AW

Meanwhile, we examine the various extension of our two-dimension world considering CIS's rule and place in it, we try to identify and describe the changes, including the causes and the communication channel on which CIS capable impacting the two-dimension related features.

1. CIS equivalent of AW: in this case, we consider CIS as a mathematical description of AW, therefore CIS equivalent of AW. In the second learning cycle, HCI generated resonance might increase AW/CIS cognitive capability as improve NW cognitive level too. The infocommunication channel is flexible it coincides with the path of energy and information flow between NW and AW (Fig. 1).

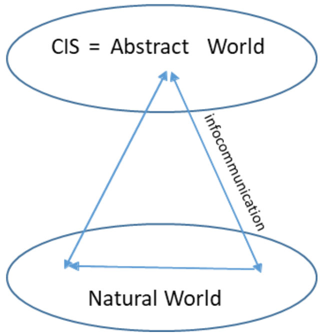

Figure 1
CIS equivalent of Abstract World

2. CIS *wedged entity between NW and AW:* In case we wedge CIS between NW and AW, meanwhile utilizing energy and matter across HCI as an input for the abstract world (AW) via the cognitive resonance as output for the natural world (NW) may transforms and extend the matter and increase the energy- related. The learning process may increase the physical world (NW) as human brain cognitive improvement. The improved (NW) capability ensure improved input for (AW), therefore it is improving too. The circle is repetitive, cognition improving both layers. Communication channel partly coincides with the path of energy and information flow (Fig. 2).

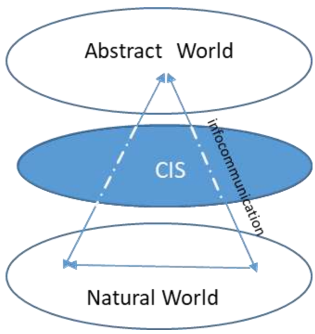

Figure 2
CIS wedged between Abstract and Natural World

3. CIS a separated entity, therefore out form NW and AW: In this case, each imputation of the NW increases the input of the AW, allowing inputs from the AW to the natural world to increase the expanse of the NW, which may be the other way around. Similarly, if we consider the cognitive system as a tool and include all a quasi-third dimension where our two-dimensional world gives and receives input through infocommunication, then the two entities grow in a parallel way, leading to an increase in cognitive abilities and knowledge. The

communication channel is separated from the channels between NW and AW, however, indirectly impacting the information and energy flow via infocommunication (Fig. 3).

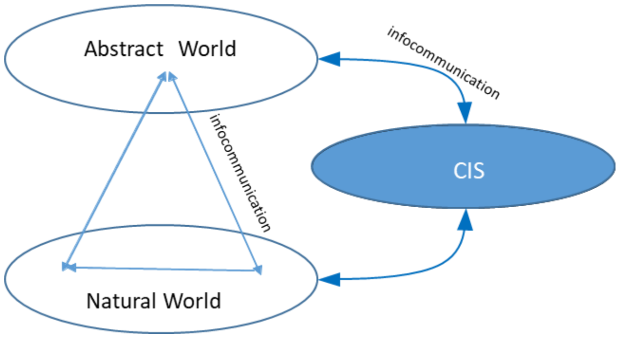

Figure 3
CIS is a separated entity, out form Abstract and Natural World

According to Wang [30] [29] there are 19 different CI factors in the relation of Software, however, the list might be extended with the below:

"*20. Flexible usage of infocommunication as a channel and methodology and tool utilizing the synergy generated across HCI as a cognitive resonance, between dimensions, independently of the location if CIS in the IME model.*"

Thus, the emphasis in the relation of the architecture on those components, that focus on learning via HCI, as the traditional machine learning methodologies and heuristic, statistic (regression, classification, etc.) approach resulting in the expected and reasonable output, but does not necessary provide unexpected but reasonable result by human across CIS computing.

That unexpected but reasonable output brings closer to mimic human brain capability, closer to the dreamed CIS, that seems to be as natural as possible considering humans as a natural being.

What are the expectations form the learning process?

According to MacLellan et al. "The features of HCI supporting naturalness, that related to the interaction is manifested in that (1) support the goals of users, (2) do what users expect, (3) lets users work the way they want, and (4) leverage users' experience to minimize training [19].

In case of during business analyses, if CIS is not capable of fulfilling the above-mentioned ones, the cognitive level is to be questioned. However, in the case of strategic management decision, the user expectation might create uncertainty related to the output, due to the user anticipation. The uncertainty that in relation to the exactly expected outcome, might trigger additional decision and additional learning cycle [21]. Strategic management decisions by humans consist of the general learning cycle i.e. observe, interpret, evaluate, decide that extended with the anticipation, a kind of "what-if " situation, that during HCI transformed to the knowledge of CIS. Repetitive strategic management decision making via HCI related to the same situation, in case the output doesn't meet with the expectation will trigger a new decision and learning cycle [21]. That is one of the sides, that can be interpreted based on the given situation as positive and as the negative side of the HCI. That is caused by the human anticipation build into the decision process. The risk and the reason what could be the explanation of the negative side, that due to human factors, if the output not acceptable, a human might trigger further decision circle - knowledge improvement for both sides - to get to the closest anticipated result [21]. That misleading exercise, not necessarily supports the organization in many cases, due to the time, effort, workload, in addition, might distort the reality of the output.

According to the above, the result of the cognitive resonance in the complex business environment, during use of cognitive systems, can provide a better result from many aspects, but still to be considered to find the proper technics/algorithm to be built into CIS, where infocommunication is used as a channel via HCI across cognitive resonance that supports better enterprises.

There are several methodologies of machine learning, however, HCI with cognitive resonance using info communication as a channel ensures the continuous improvement of the knowledge and cognitive level, impacting both the abstract and the natural world. Smooth stat solutions do not produce bloodless but acceptable results by not increasing the system's knowledge. Cognitive Infocommunication is an important element of the learning process because it provides the basis for cognitive resonance and plays a prominent role in the coordination of individual architectural details.

If we select an approach according to Information Theory, we should profoundly modify the models proposed by Wang [29]. As the CISs are components of the Digital Universe, i.e. CISs are composed of bits forming data that are embraced by formations to be represented by the carbon agent. The abstract world should be interpreted as the realm where the computing processing happens; the processes manipulate the formations automated way, primarily syntactically so that the data embedded into formations could be interpreted by carbon agents as information that owns semantic interpretation.

In this approach, each input coming out of the natural world increases the information content of the Digital Universe within the abstract world (Fig. 4). The information contained within an Information System having Data Collection Management Systems cannot increase through running queries and any data processing algorithms as the symbiosis of the program code and the data together defines the complexity of the content (see Benczúr et al. [5]).

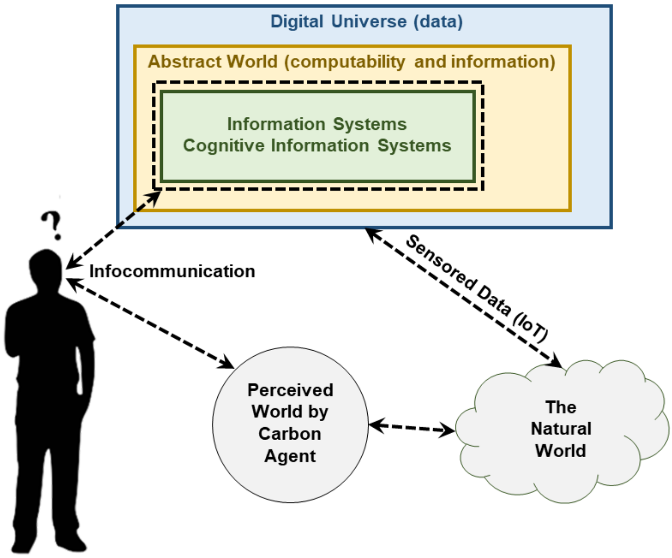

Figure 4
Cognitive Infocommunication in the context of Digital Universe and Cognitive Information Systems

Within a CIS, the set of data and algorithms constitute the information content, i.e. the computation may produce data encompassed in formations that were not still stored eventually in the system, but it does not augment the overall information content of the system. However, outputs from the abstract world within the Digital Universe to the natural world can enhance the knowledge of the carbon agent through perception and interpretation of the meaning of the communicated data. The carbon agent through cognitive activities creates actionable knowledge out of the information that was conveyed through formations. The abstract world consists of two parts, one part is the set of Information Systems that embodies the computational capabilities and the data stored in formations represented by bits, the other part is the set of Cognitive Information Systems that contain the most modern algorithms for data processing, visualization, and toolset to achieve a high level of cognitive resonance between the carbon agent and the silicon agent.

6 Cognitive Infocommunication in the relation of CIS & its architecture

According to Baranyi et al. [4], Cognitive Infocommunication is used to refer to devices and networks which can assign resources and functionalities in dynamic and intelligent ways. CIS is capable to elaborate information dynamically and intelligently, meanwhile, UBMSS missed those functionalities and dynamism [3].

That calls the attention of the importance of cognitive architecture with cognitive functions and appropriate cognitive level, the integration that allows the development of cognitive entities. There is a view that human cognitive capabilities and human intelligence are emergent properties that cannot be separated from the physical, biological, neurophysiological and higher-level bases of our mental existence [6]. However, the social and technological context of our interactions with other humans and ICT further influences the kinds of mental and physical work that we can perform [6], [12]. That is one fact that explains and highlights the importance of cognitive resonance, that enable human a CIS to improve their cognitive level. This is what only the real cognitive information system capable of, via inter Cognitive Communication and Cognitive Infocommunication. The architecture focuses on the representation of the information of both entities, within human and carbon agents.

Conclusions

The disciplined architecture approach can help in understanding the cognitive structure of information systems. The proposed application of architecture description methods allows a systematic depiction of a complex situation, where several interdisciplinary principles play roles, i.e. cognitive sciences, information systems analysis and design, formal architecture methods, and Data Science. The proposed method assists the development and construction of CISs at small and medium-sized enterprises that build up their systems from heterogeneous components exploiting open source software solutions, supports and utilize the synergies of cognitive sciences trough Cognitive Infocommunication improving the value of information, knowledge and learning.

The Enterprise Architecture helps reconcile the information exchange and infocommunication between the relevant components of a Cognitive Information Systems, namely, between automated Business Processes and actors/roles/business Entities. The architecture of the most recent Information Systems contains several components that compel serious cognitive efforts on the side of the carbon agent to keep in hand the overall processes and information exchange, to orchestrate the ensuing activities. The most modern Information Systems contain IoT elements (Internet of Things, actuators/sensors, etc.) and a huge amount of data that are harvested from IoT elements through Edge and Fog computing. The data are stored in an unstructured format in Data Lakes, in a structured format in Data Warehouses. To make it useful for the carbon agent, the interplaying of several methods and tools is required as visualization of the produced data, the data should be extracted and processes into meaningful format exploiting the available toolset of Data Science. The Cognitive Infocommunication fosters the bidirectional data stream to realize the cognitive resonance primarily on the side of the carbon agent. On the side of silicon agent, the cognitive resonance can be achieved through appropriate representation of the analogue and digital universe to provide an effective feedback for the carbon agent.

The success of an effective Cognitive Infocommunication in realizing cognitive resonance, will contribute to the improvement of the quality of Information Systems, this achievement will enhance the reliability and trust, in Information Systems.

Due to Cognitive Infocommunication integrative cognitive processes, where the capabilities of the human brain could be extended, not only through the equipment, but also within the interaction with the capabilities of any CIS. Cognitive Resonance improves the knowledge and the effectiveness of HCI making it more and more relevant, therefore, based on our view, it contributes significantly to part of Cognitive Infocommunication.

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Experiencing the Sense of Presence within an Educational Desktop Virtual Reality

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Abstract: This study examines the sense of presence in MaxWhere desktop virtual reality. Thirty-one people participated in the research. The participants spend about fifteen minutes in the virtual environment. For measuring presence, the Igroup Presence Questionnaire (IPQ) was used. The results showed that more automatic navigation positively relates to spatial presence. This research also measured the participants' level of experience with the VR software. A significant difference was found in the spatial presence and experienced realism: the more experienced users gave higher ratings on both subscales. At the same time, the involvement and the general presence scores were similar in the two groups, which is advantageous in education as the presence is positively related to the learning outcome.

Keywords: desktop VR; presence; MaxWhere; virtual reality

1 Introduction

Digital transformation in education aims to arise the interest and engagement of students and help them in their learning experience. Cognitive infocommunications join forces of different research areas in order to reach an effective interaction between humans and computers and take full advantage of human cognitive capabilities with the help of infocommunication devices [1, 2].

There are several trends in digital transformation in education, such as gamification, personalized learning, augmented and virtual realities (VR). The latter can be present in education as virtual lecturing [3], virtual training [4, 5], field trips in special areas or museums [6]. VR is also getting attention in the industry [7] thus it is to introduce the virtual reality in the education of engineers such as different simulations in virtual laboratories [8, 9, 10]. Virtual reality can engage and motivate the students to acquire knowledge [11]. Moreover, it provides visualizations and interactions that are impossible or too expensive to perform in a real environment. According to a meta-analysis, virtual reality-based instruction is highly effective in K-12 and higher education [12].

Virtual reality means a three-dimensional, simulated environment that can be realized through different software and hardware. Virtual realities can be classified as full-immersive and non-immersive virtual realities. Full-immersive VR provides a high degree of interactivity, special input devices and a 360° view with the help of a CAVE system or a head-mounted device (HMD). These special and expensive devices are rarely available in an ordinary educational institute. Therefore, the non-immersive or desktop virtual realities are more popular in the field of education as there is no need for special equipment only a computer and maybe a classic control device (mouse). These virtual realities show the simulated environment on a 2D display.

This paper is structured as follows. Section 2 shows the presence phenomenon and the process of immersion. Section 3 provides an overview of virtual realities in education and its relationship with the sense of presence. Section 4 presents the aim of the study and Section 5 shows the methods of this research such as the subjects, the measured variables, and the process. Section 6 presents the result of this study and Section 7 is a further discussion of these results. Finally, the results are briefly summarized in the Conclusion section.

2 Presence

Presence is a state of consciousness, a psychological phenomenon, the sense of “being inside” the virtual environment [13]. Despite their name, the non-immersive virtual realities can also provide a sense of presence to their users. Presence is a human reaction to immersion, which is a more objective variable that depends on the devices and the software used for the simulation [14]. While immersion is a technology factor, presence is a subjective experience. Different individuals may experience different levels of presence in the same virtual reality because people have varying susceptibility to feeling present in a virtual environment. Immersive tendency and visual ability are relating factors to this individual variability [15].

The first step in the process of experiencing presence is that the technology immerses the users’ senses and body into the virtual reality. Then different cognitive processes foster the creation of the mental model of the VR and the immersed body. Then, finally, the user experiences the sense of presence, the feeling of being inside the virtual environment [16]. Different factors contribute to the sense of presence such as control, realism, distraction and sensory input [17]. For experiencing the sense of presence, it is important for the user to have control over the environment. Thus, the controller device can play a role too. A naturally mapped interface requires less thinking about controlling, thus the user more effortlessly feel “inside” the environment. The controller naturalness is also a subjective variable, as the users have different experiences with a different controller. The perceived naturalness of the controller could predict the spatial presence [18].

3 Virtual Reality in Education

In the theory of multimedia learning, Mayer emphasizes the importance of the limited cognitive capacity of humans. This means that only a limited amount of information can be processed by the visual and auditory channels. According to this theory, learners can engage in three kinds of cognitive processing (or cognitive load) during learning: extraneous, essential and generative [19]. Cognitive load is the relative demand imposed by a particular task, in terms of mental resources required [20]. Extraneous cognitive processing refers to the cognitive processes which do not serve an instructional goal. For example, a sluggish interaction with the virtual environment because of poor design or lack of experience. Essential processing is the selection of relevant information, and generative cognitive processing refers to the organization of these materials. This latter allows a deeper understanding of the learning material [19].

It is widely accepted that virtual reality can enrich the students’ educational experience. Furthermore, VR can enhance the learning outcome of students. The sense of presence positively influences the students’ interest and motivation to interact with the simulation [21, 22]. The learning outcome is affected by the presence: they have a positive relationship in just a ten minute session [23]. Earlier research suggested that there is a direct relationship between presence and the learning outcome, based on their structural equation modeling approach [24]. A recent research [22] also investigated the process of learning in VR with the help of structural equation modeling. Their results did not support the previous results with the direct relationship. They found two general paths: an affective and a cognitive one by which desktop VR led to increase the learning outcome after a VR lesson. The affective path led through VR features, presence, intrinsic motivation and self-efficacy; the cognitive path went through VR features, usability, cognitive benefits, and self-efficacy [22]. In this model, the sense of presence arises from VR features such as the degree of realism and control factors. This initial relationship, that higher fidelity causes more presence was similar to earlier research, but there the higher fidelity also caused less learning presumably due to the irrelevant sensory information [25]. However, in this new model, the role of presence in learning depends on other factors such as intrinsic motivation and self-efficacy [22]. To sum up, a higher sense of presence is related to better learning outcomes, but other factors such as intrinsic motivation and self-efficacy mediate this relationship.

4 Research Objectives

Virtual reality is part of the digital transformation of education, and it is already started to spread in different educational institutions. The Széchenyi István University is promoting the use of virtual education and the VR Learning Center of the university plays a role in developing basic methodologies for VR-based education. The used VR platform is the MaxWhere [26] virtual reality. This desktop VR enables the teachers and students to create and share 3D learning spaces, where any web content, document, video or image can be displayed. The spatial arrangement helps the student to understand the structure of the learning material [27]. Moreover, there are also virtual laboratories for engineering students [8, 9, 10]. The MaxWhere VR was already in the focus of numerous scientific research [27, 28, 29, 30], but none of them measured the sense of presence, however, it relates to the learning outcome.

The aim of the current study is to investigate the sense of presence in MaxWhere virtual reality. This research also investigated whether there is a difference between novice and more experienced users in experiencing presence. As the focus was on one specific VR we did not compare different navigational devices, but the navigational experience of users.

5 Methods

5.1 Subjects

Thirty-one (6 female and 25 male) individuals' data were analyzed form the original thirty-six participants. Five people were excluded due to data loss or other problems during the experimental procedure. The mean age was 20.5 years (SD: 3.4).

5.2 Measures

5.2.1 Presence

The sense of presence was measured by the Igroup Presence Questionnaire (IPQ) [16]. This 14-item questionnaire has three subscales: spatial presence, involvement, and experienced realism. Spatial presence measures the sense of being physically present in the simulated environment, involvement assesses the awareness devoted to the virtual reality. The experienced realism factor shows the subjective experience of realism in virtual reality. IPQ contains a general item, which measures the general presence: *In the computer-generated world, I had a sense of 'being there'* [16]. Measures were made on seven-point scales, with lower scores indicating disagreement. All subscales had an acceptable level (α > 0.7) of reliability in the present study.

5.2.2 Navigational Experience

For measuring the participants navigational experience in the virtual reality, we created a five-item scale: I moved confidently in the space", "I felt that I was controlling my movements in space", "I had difficulty navigating to the place where I wanted to go" (reverse-scored item), "Navigation in virtual space was automatic for me", "I felt natural moving in the virtual space". Participants had to indicate their agreement on a ten-point Likert-scale. The Cronbach's α of the scale was 0.883, therefore this scale can be considered as reliable.

5.3 Procedure

In the experiment, the MaxWhere [26] desktop virtual reality was used. After giving consent to take part in the research, users navigated in the virtual reality and solved different tasks for about 15 minutes. After this navigating session they filled the Igroup Presence Questionnaire, they rated their navigational experience and answered basic demographic questions. They also had to indicate their prior MaxWhere knowledge.

6 Results

Means and standard deviations for the IPQ subscales and the navigational experience scale are presented in Table 1.

Table 1

Means and standard deviations of the measured variables

	All participants		Novice		More experienced	
	Mean	SD	Mean	SD	Mean	SD
Navigational experience	7.04	2.19	6.64	2.44	7.67	1.53
IPQ – General presence	2.7	1.7	2.4	1.5	3.2	2.0
IPQ – Spatial presence	3.06	1.27	2.67	1.06	3.67	1.34
IPQ – Involvement	2.6	1.27	2.45	1.3	2.83	1.2
IPQ – Experienced realism	1.82	1.04	1.5	0.9	2.32	1.04

6.1 Navigational Experience Correlates with the Presence

The Pearson correlation showed a statistically significant positive correlation between the individual navigational experience score and the spatial presence scores r(29) = 0.497, p = 0.004. To be precise, the more automatic navigation correlated with a higher sense of spatial presence.

6.2 Novice and Experienced Users

Subjects were divided into two groups based on their prior experience with this virtual reality. Those, who used already this virtual reality at least one hour before the experiment, were the experienced users and those who had no or up to one-hour experience were considered as novice users. Twelve participants were in the experienced group and nineteen in the novice group. The mean scores and standard deviations of each variable for each group are presented in Table 1. The mean scores of IPQ subscales are summarized in a boxplot in Fig. 1.

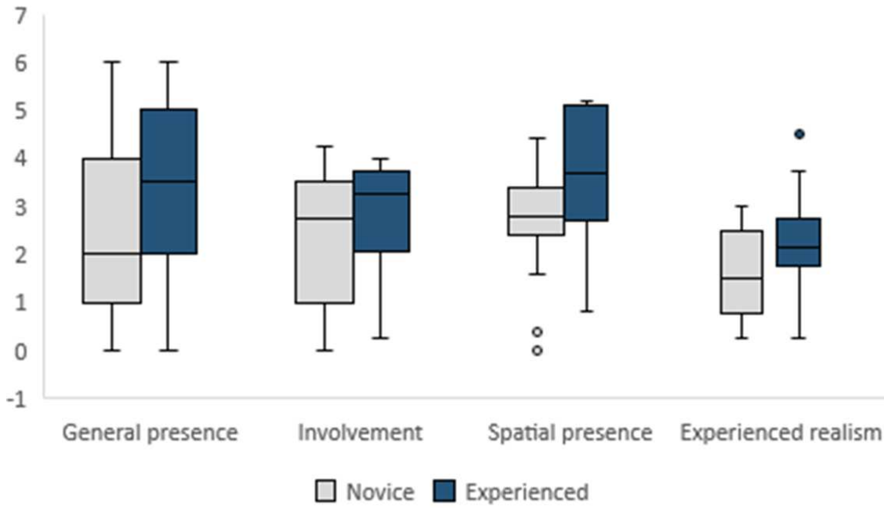

Figure 1

Scores on IPQ subscales among novice and more experienced participants

First of all, we tested whether the navigational abilities of the participants are roughly equal in the two groups. For this, we used an independent sample t-test. The test showed that no significant difference (t(29) = -1.26, p = 0.217) was found for the navigational experience scores of the novice (6.64) and the experienced (7.67) group. Thus, the differences in sense of presence between the two groups are not related to differences in their navigational ability.

The independent sample t-test showed no significant difference between the novice (2.4) and the experienced (3.2) group for general presence ($t(29) = -1.37$, $p = 0.182$). The Mann Whitney U test ($U = 92.5$, $p = 0.392$) showed no significant difference for the involvement scores between the two groups (novice: 2.447, experienced: 2.833). The level of general presence was similar in the two groups and also the involvement, which is the attention devoted to the environment.

The results showed that spatial presence ($t(29) = -2.21$, $p = 0.035$) and experienced realism ($t(29) = -2.23$, $p = 0.034$) were significantly higher in the experienced group (SP: 3.67; REAL: 2.32) than in the novice group (SP: 2.67; REAL: 1.5). Hence the novice users experienced less spatial presence than those who had at least one hour of prior experience with the software. Furthermore, they rated the virtual environment less realistic than the more experienced participants.

7 Discussion

The aim of this study was to investigate the sense of presence in MaxWhere virtual reality: its relationship with the subjective navigational experience and the differences between novice and more experienced users. The results showed positive correlation between the navigational experience and spatial presence scores. Furthermore, the more experienced users gave higher ratings on the spatial presence and experienced realism subscales, but the general sense of presence and involvement did not differ between these two groups.

The positive correlation between the subjective navigational experience and the spatial presence means that those who rated the navigational experience more automatic and natural, experienced a higher sense of spatial presence in the virtual environment. This easier and more automatic navigation can also relate to the controller naturalness. In an earlier study, the controller naturalness positively predicted the spatial presence [18]. A naturally mapped interface requires less thinking about controlling the virtual reality and allows users to feel in the virtual environment more effortlessly. In the present study, only one type of controller was used, but the perceived navigational experience closely relates to this construct.

In this study, the level of experience with the software was a key factor. Based on this, the participants were categorized as novice and more experienced users. The latter ones had at least one-hour prior experience with the MaxWhere software. The scores on the involvement subscale did not differ between the two groups: they devoted roughly the same amount of attention to the virtual reality and the experimental task. Thus, external factors did not influence the difference between these groups, neither group was disrupted from the VR more frequently. Also, the general sense of presence, the sense of “being inside” the virtual environment did not differ between the groups. Thus, the overall sense of presence was not related to prior experience with the software.

The spatial presence score, which measures the sense of being physically present in the VR, was higher among the more experienced users. In early VR studies, the most common difference between novice and experienced users was the navigation ability [36], but in this study, we found no significant difference in the navigational experience of users with different levels of experience. But they could have more cognitive resources to the details of the VR as they could use the software more automatically. For example, the more experienced users could have used the gesture-based activation mode of the smartboard, instead of the clicking on the corresponding button. But this variable was not measured in this study. For more information on the gesture-based method and spatial navigation in this virtual reality, the study of Sudár and Csapó (2019) [29] is recommended.

The other difference was in the score of experienced realism, which was also higher among experienced users. Presumably, they could use their more cognitive resources to observe the details of the VR. Another possible explanation relates to the fact that prior rating of the same virtual reality sensitizes observers to its different features, which could result in different presence scores [32]. Namely, the more experienced users can have more concrete expectations about the VR. Besides, the novice participants could genuinely compare the virtual experience to the reality, which also can cause the lower ratings on the experienced realism subscale. The experienced realism scores were the lowest for both groups among the IPQ factors. This could be since the MaxWhere virtual reality was not intended to replicate a real place, but to create a virtual space for learning and working. The high representational fidelity could evoke a stronger sense of presence but less learning, presumably due to the irrelevant sensory information [25].

The overall pattern of these results shows that the more experienced participants gave similar or higher ratings of different presence factors. Therefore, this VR is not just a cool technique to enrich the students' educational experience, but repeated use can extend the sense of presence. Given that presence can be a key factor in learning outcomes [22, 23, 24], it could be a way to increase the students' motivation of student and self-efficacy [22] which leads to better learning outcomes. But of course, presence is not the only fundamental variable in a virtual learning environment the educational materials and resources also have a high impact on learning outcomes [33].

Conclusions

This study examined the sense of presence, in MaxWhere virtual reality. The results showed that more automatic navigation positively relates to spatial presence. A significant difference was found in the spatial presence and experienced realism: the more experienced users gave higher ratings on both subscales. But both the involvement and the general sense of presence were similar, which is advantageous in education, as the presence is positively related to the learning outcome.

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