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The Multi-Method Analysis of the Educational Use of ICT-Devices

Measurement of the Uncontrolled Use of ICT-Devices among College Students

Summary of Doctoral (PhD) Thesis

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1. The topic of the PhD thesis

Regarding the impact of the devices of modern information and communication technology on human beings, three attitudes can be distinguished. According to technological optimists modern technologies have positive effects on our cognitive functions and way of thinking. From the point of view of social pessimists, the effects of modern technologies are fundamentally negative, and we may be defenceless against these effects. Finally, biological optimists agree with the two aforementioned groups on the idea that modern technologies actually result in changes in a lot of areas, but they think that our biological system can adapt to these changes just as it did at the time of former technological revolutions (e.g. at that of the invention of writing) (Pléh, 2011; Pléh, Krajcsi, & Kovács, 2003). The basic issue of the thesis is whether we are really exposed to our information- and communication technology (ICT) devices, or, as biological optimists think, we adapt to the altering environmental requirements. Therefore, the core concept of the dissertation is the concept of ICT-control, which refers to the degree of consciousness in the ICT-usage, and the question is how this factor influences our learning performance while using ICT-devices.

The topic of the dissertation is at the borderline of psychology and pedagogy – mainly of cognitive pedagogy. It focuses on the exploration of cognitive and affective determinants that influence the success of learning in an electronical learning environment. The other scientific domain that the main topic of the dissertation may belong to is the domain of self-directed learning, within which it can be linked with the self-related concepts of self-directed learning, more precisely, to the exploration of control-processes (Molnár, 2002). The dissertation also reaches conclusions concerning each component of self-directed learning (regulation of processing modes and the choice of cognitive strategies, regulation of the learning process and the use of metacognitive knowledge and skills in the learning process, regulation of the self and the choice of goals and resources) (Boekaerts, 1999).

2. Theoretical framework

The external and internal conditions of effective learning keep changing in electronic learning environments. The roles of both teachers and students undergo a transformation. The activity of the learner is unquestionable in the process of learning. However, the teacher is not the source of information any more, but he/she is the supporter of the student helping him to find his way in the huge amount of information. Both the ways of the acquirement of knowledge and the material students have to learn are changing in our changing world (Pléh, 2006, 2010, 2011). Self-directed learning is increasingly appreciated, learning can take place not only in official educational institutions, but also in informal ways; it lasts lifelong, and it extends to all fields of life (Komenczi, 2009). Consequently, the strategies of self-directed learning gain increasing importance in electronic learning environments.

The dissertation attempts to collect the changes in our cognitive functions, those that are the results of technology usage, contributing in this way to the issue of whether the networked culture, a more recent cultural formation that falls in line with the cultural formations specified by Merlin Donald (2001), entails the radical transformation of our cognitive architecture (Komenczi, 2009; Pléh, 2011).

The usage of modern technology may transform our cognitive functions. It affects our reading ability, which, as a result, becomes more superficial and careless. This does not facilitate the emergence of deep thoughts about what we have read (Carr, 2010). Our thinking is getting more and more intuitive, we tend to seek the information we ourselves could also find out (Barr, Pennycook, Stolz, & Fugelsang, 2015). Besides, the use of search engines is not evident, either (Pléh, 2011). We lack the critical thinking skill, so important for the selection of information (Mason & Rennie, 2008). Of all the orientation systems of our attention it is the evolutionally more ancient external orientation system that our modern devices have a vital impact on (Rothbart & Posner, 2015). By engaging all our senses, they attempt to draw our attention from our primary tasks (Wilmer & Chein, 2016). The multimedia learning environment means a great challenge for the executive attention, because in this context, the maintenance of focused attention requires massive efforts (Rothbart & Posner, 2015). Our memory function is also subject to transformation. As the results of some research show, we adapt to the changing conditions, so we tend to store the place where we can find the information rather than the information itself. (Sparrow, Liu, & Wegner, 2011).

The multitasking activity, i.e. shifting our attention between simultaneous tasks, also has an effect on the working memory function. The working memory capacity plays a key role in the effectiveness of multitasking; however, the frequency of multitasking does not necessarily depend on the working memory capacity of the particular person. So the fact is that the multitasking activity is not necessarily typical of students who are really better at it (Sanbonmatsu, Strayer, Medeiros-Ward, & Watson, 2013). The effective multitasking also challenges our executive functions, such as the skill of changing, cognitive flexibility (the flexible adaptability to the demands of the new task), the skill of inhibition (because while dealing with one task, we have to inhibit the factors required by the other task) (Loh & Kanai, 2015). These executive functions also play an important role in the controlled ICT-use during the learning process.

Our intellectual abilities are also changing. The score of the performance on intelligence tests is increasing continuously (Flynn, 1984). This can be explained by the positive effect of technology. However, if we examine the results on other tests, e.g. the scores achieved at the verbal SAT (university preliminary examination), which, unlike the results on verbal intelligence tests, stagnate, the conclusions regarding the effect of technology on intelligence can be rather different (Greenfield, 2009). These higher cognitive functions play an important role in learning, so the effect of modern technology on our cognitive function may also affect the learning achievement in an indirect way.

In electronic learning environments (where the learning environment involves a high number of electronic devices, or the primary place of learning is the computer) multitasking is typical. Learning is more effective when it is carried out with focused attention; however, the degree of negative impacts of multitasking depends on several things. It depends on the type of the concurrent tasks, on the form and the timing of the secondary task, and it depends on how much time the secondary takes away from the primary task (Courage, Bakhtiar, Fitzpatrick, Kenny, & Brandeau, 2015).

It is not the use of ICT-devices per se that has negative consequences, but rather their inappropriate and uncontrolled use. In this way, the negative impact of these devices on learning may be mediated by their maladaptive use, i.e. if they are not used at the right time, or for the right period of time. As an example, it is an improper point of time when ICT-devices are used in the classroom or during a lecture, which may not only impair the performance of technology users, but also that of those who can see their multitasking activity (Sana, Weston, & Cepeda, 2013). In this case the secondary task carried out with ICT-devices results in cognitive overload, and hereby, it does not leave any free resources for the deeper processing of the curriculum, and in this way it will impair the performance. Another example of use in an improper point of time is a bedtime activity with infocommunication devices, which has a harmful effect on sleep quality and leads to the deficit of our cognitive function, which also has a negative effect on the learning achievement (Wolfe et al., 2014). Besides, the issue of the duration of the secondary task is also of utmost importance, since, by taking up time, the use of the device may also have a negative effect on the learning performance. If the secondary task – for example the use of social media, or chatting – takes away too much time from studying, it also has a negative effect on learning (Junco, 2012).

The question is what background factors can be detected behind uncontrolled ICT-use. These background factors can be different personality features, like impulsivity, sensory seeking and locus of control. Higher rates of impulsivity – especially negative urgency –, and sensory seeking – especially disinhibition – show a positive correlation with problematic ICT-use, and a negative correlation with learning achievement (Cladellas, Muro, Vargas-Guzmán, Bastardas, & Goma-i-Freixanet, 2017; Contractor, Weiss, Tull, & Elhai, 2017; Hyun, Park, Lee, & Kim, 2014). Maladaptive use of ICT-devices is typical of external locus of control (when people think that they do not have any power over what is happening to them), however, there are no differences in the frequency of general ICT-use between the external and internal locus of control (Li, Lepp, & Barkley, 2015).

Apart from personality background factors, uncontrolled ICT-use can also be motivated by the checking habit, which we tend to develop when using our modern devices (Oulasvirta, Rattenbury, Ma, & Raita, 2011). This leads to habitual distraction, which means that our ICT-usage becomes habitual and hereby undermines – often in an unobserved way – our focused attention. Such habitual attitudes mean the largest challenge for the conscious control skill, since these are fully automated behaviours, and in many cases, students are not even aware of the fact that their attention has been distracted for long minutes (Aagaard, 2015). Consequently, we may think that the best solution would be if we refrained from technology use while studying. This, however, can also have harmful effects on the conscious attention, because the lack of technology often results in heightened anxiety levels in learners (Cheever, Rosen, Carrier, & Chavez, 2014). So the solution is teaching controlled ICT-usage skills rather than the prohibition of technology use.

The results of my research suggest that the controlled ICT-use during the studying process can reduce the negative impact of the multitasking activity on the learning performance. If the learner uses adequate timing for the secondary task (e.g. he/she shifts his/her attention after and not before completing subtasks), if he/she controls the time that he/she spends with the device while studying (e.g. the secondary task lasts not too long), the learning performance will not be impaired to a large extent. However, to achieve this, there is a need for such skills; the student should know his/her own cognitive function and the requirements of the task, or the costs of task shifting. To achieve this, the key ability is metacognition (Rosen, Lim, Carrier, & Cheever, 2011).

3. Purposes

The main concept of the investigations introduced in this dissertation is controlled usage and ICT-control. The dissertation presents three investigations which attempt to point out the relationship between ICT-control and the following fields: the cognitive and personality background factors and ICT-usage habits.

The common goal of the presented investigations is to gain better knowledge of the special features of the new concept of ICT-control, as well as its relations with the factors that are in connection with the learning performance in electronic environments. Based on the results of the investigations, the dissertation aims to point out the appropriate interventions in order to find a way to make learning more effective by means of controlled ICT-use.

4. Research

4.1. Research strategies

The dissertation introduces a new construct, the concept of ICT-control, as well as a questionnaire for measuring this concept. The ICT-control is a part of the self-directed learning ability, which has a really important role in electronic learning environments in the promotion of effective learning. It refers to the extent of the personal control over the ICT-devices. Controlled ICT-usage or internal ICT-control means that people practise control over the use of ICT-devices, use these devices consciously and not habitually, they practise self-controlled ICT-use against internal and external disturbing factors. Uncontrolled ICT-usage or external ICT-control shows that the user has a lower level of self-control and consciousness in his ICT-usage.

The questionnaire to measure ICT-control was evolved after the review of the special literature and based on Rotter's (1966) internal-external locus of control scale. The first version of the questionnaire contained fifty items, which were answered by 57 college students. Based on the data, I examined the distribution of every item (as well as other indicators, like the intelligibility of the item, and the evaluation of the persons with regard to how certain they were of their answers to the items). As a result of the inquiry, 24 items were omitted, so the final version of the questionnaire contains 26 items.

Apart from the ICT-control questionnaire I also use other questionnaires (to measure ICT-use and personality background factors) in my research; I use computerized cognitive tests for measuring cognitive abilities, and a paper-pencil intelligence test. The questionnaires were on online platform. My studies are correlational.

My research subjects were university students in each of the studies. This has two reasons. Firstly, it is in this age group that the control over learning and ICT-usage becomes increasingly important, since this is when the control of parents and teachers over them decreases (Calderwood, Ackerman, & Conklin, 2014). Secondly, this is the age, when students are expected to have the cognitive skills required for effective multitasking (the skill for controlled attention, executive functions like working memory, inhibition, flexibility in shifting, metacognition) (Courage et al., 2015).

4.2. First research – The relationship between ICT-control and general ICT-use, ICT-activities in groups of college students

4.2.1. Methods

The main research question was the following: What kind of ICT-usage habits are typical of the people showing controlled and uncontrolled ICT-usage (how often do they use the ICT-devices and what kind of activities do they do with these devices)?

Subjects were university students from nine Hungarian higher educational institutions (N=154, mean age: 21,86, standard deviation: 4,68).

Measurements were based on questionnaires. The first one was the ICT-control questionnaire (Cronbach alfa: 0,765). The second questionnaire was a general ICT-usage scale (the first section of this scale measures the frequency of the use of different ICT-devices, the second section measures the frequency of the activities done with such devices). The results of the factor analysis show six factors corresponding with the results of some earlier research (Faragó, Soltész, & Pléh, 2015). They are as follows: social usage, e-mail and administration, professional goal-oriented usage, reduction of boredom and relaxation, media consuming and listening to music, and telephoning.

Subjects filled in the questionnaires in an online form, the data collection took place between October 2016 and May 2017.

4.2.2. Results and conclusions

Regarding internal and external ICT-control there was a difference in the frequency of smartphone usage and traditional mobile phone usage. Smartphone usage was more frequent in the case of uncontrolled ICT-usage, whereas traditional mobile phone usage increased in the case of controlled ICT-usage. The usage of smartphone in itself can promote the habitual behaviours that can make the controlled use of devices more difficult during the studying process (Oulasvirta et al., 2011). Thereby the frequent use of this technology may also have a negative impact on learning performance. Besides, the impact of the use of smartphones (and other ICT-devices) on learning performance can be mediated by the direction and the way of the usage.

From the perspective of ICT-control, two ICT-activity factors showed difference in activity frequency; firstly, reduction of boredom and relaxation, secondly, social usage. These activities are more common with people with uncontrolled ICT-use. If, besides studying, social media is a secondary task, it can have a harmful effect on performance, when it distracts our attention from the learning task for a long time (Junco, 2012). ICT-usage motivated by boredom reduction and relaxation may occur during the learning process, but it is important to emphasize that these activities have a positive effect (i.e. a relaxing effect) on learning, if they only last for a short period of time and if we can return to our primary learning task (Junco, 2012). This means that relaxation with the device takes place in a controlled form.

Finally, I made up four groups with Cluster analysis based on the frequency of general ICT-use and the form of ICT-control (uncontrolled ICT-usage-rare ICT-use; uncontrolled ICT-usage -frequent ICT-use; controlled ICT-usage-rare ICT-use; controlled ICT-usage - frequent ICT-use), and I compared these clusters from the point of view of the frequency of the activities carried out with ICT-devices. Results show that in each ICT-activity factor, the average of controlled ICT-usage and rare ICT-use groups always had the lowest frequency, whereas the highest frequency occurred in the groups of uncontrolled ICT-usage and frequent usage (except for the media consuming and music listening factors). By examining the clusters that represented the second highest frequency in the ICT-activity factors, and based on the results it could be stated that regarding the frequency of e-mailing and administration and the frequency of telephoning, it is probably the frequency of ICT-use that counts. In contrast, the frequency of social usage, boredom reduction and relaxation with the device were rather determined by ICT-control.

Uncontrolled ICT-usage seemed to be linked with the frequency of smartphone usage, the frequency of the social usage of ICT-devices, and the ICT-activities motivated by boredom reduction and relaxation. These activities, if they occur in an uncontrolled way while studying, have a negative impact on the learning performance. So conscious ICT-usage has an important role in the activities that can be harmful to studying and maintaining focused attention (boredom reduction, relaxation and social media use). It means that, if we want to do such activities, even while studying, in a way that it should not result in performance loss, then it is essential that we should learn the skill of controlled use of ICT-devices during the learning process.

4.3. Second research – The personality background factors of ICT-control; impulsivity and sensory seeking behind ICT-control in a group of college students

4.3.1. Methods

The research issue of my second investigation was the following: What kind of relationship is there between ICT-control and impulsivity and sensory seeking, and, if there are any connections between ICT-control and student achievement, can this relationship be mediated by impulsivity and sensory seeking?

The subjects were again college students (N=125, mean age: 22,54, standard deviation: 5,73).

The survey was carried out with an online questionnaire. Student achievement was measured by self-declaration, i.e. I asked participants about their grade point average in the previous semester (if they were first-year students, I asked them about their last year-end grade point average in the secondary school). Besides, I used the ICT-control questionnaire (the value of Cronbach alfa was 0,811), and two other questionnaires for measuring impulsivity and sensory seeking. I used the Hungarian adaptation of the Barratt Impulsivity Scale (BIS), which has three subscales, namely the lack of self-control, impulsive behaviour and impatience (or in other studies: negative urgency) (Varga, 2014). For measuring sensory seeking, I used the Hungarian adaptation of the 8-item Sensory Seeking Questionnaire, which includes four subscales, such as sensation seeking, adventure seeking, disinhibition and boredom (Mayer, Lukács, & Pauler, 2012).

The participants filled in the questionnaires in an online form, the data collection took place between September and October 2017.

4.3.2. Results and conclusions

The results of my second research did not explore any connections between ICT-control and average grade point. The possible explanation of this result is that the higher average grade point is over-represented in this research sample; the average of the sample is really high. So the average grade point does not probably differentiate well enough among the students. Due to the lack of connection, I could not examine what modifying role impulsivity and sensory seeking may play in this relationship.

However, I examined the difference between controlled and uncontrolled ICT-usage from the point of view of impulsivity and sensory seeking. Results showed higher impulsivity (particularly higher impatience and lack of self-control), as well as higher sensory seeking (particularly higher disinhibition and boredom susceptibility) related to uncontrolled

ICT-usage, unlike with persons with controlled usage. There were no differences between the two ICT-control groups in the subscales of impulsive behavior, sensation seeking and adventure seeking.

Of the subscales of sensory seeking, the anonym world of the internet favours disinhibition (Chmiel et al., 2011). In many cases, the liberation from inhibitions may lead to the compulsive use of ICT-devices (e.g. in the case of social interaction anxiety, the online forms of communication are not so stressful as face-to-face interactions) (Lee, Chang, Lin, & Cheng, 2014). Consequently, it is possible that it is disinhibition that is in the background of the more frequent social media use in uncontrolled ICT-usage. The other subscale of sensory seeking, in which a difference manifests itself, is the intolerance against boredom. Recent research has shown that students tend to digress and are subject to distractions if the lecture is not interesting enough for them (Gupta & Irwin, 2016), mainly due to the rewarding nature of the internet and the social media. So uncontrolled ICT-usage can have a negative impact on the learning performance since these people show reduced boredom tolerance against activities, which are not interesting enough for them, therefore they are easily tempted by relaxing activities. Relaxing activities do not always do good to the performance (because the more time students spend with such an activity, the less time they spend studying). So the background of the higher frequency of the ICT-activities motivated by the reduction of boredom and relaxation is probably the boredom intolerance of people with uncontrolled ICT-usage.

Within impulsivity, the lack of self-control goes with uncontrolled ICT-usage, which is understandable, because ICT-control is also a control-function (so the self-control scale is suitable for measurement of the convergent validity of ICT-control). Recent research has shown that impatience (or negative urgency) leads to problematic ICT-usage in the state of intensive distress. In such situations, the rewarding nature of ICT can help to reduce the negative emotional state (Contractor et al., 2017). This kind of stimulating and rewarding nature is also typical of the social media (Levenson, Shensa, Sidani, Colditz, & Primack, 2016). So in the background of the results of the first research, which demonstrated more frequent social media use with people with uncontrolled ICT-usage, can be higher impulsivity, and especially the higher impatience and the lower self-control of such people.

Due to the correlational nature of the research, it has not been decided yet whether ICT-usage causes higher impulsivity, disinhibition and the features that are responsible for the impaired tolerance of boredom, or the other way round: those who show these features are more susceptible to the maladaptive use of ICT-devices. However, we can state that the internet is a continuous challenge for our self-control and cognitive control, and these control functions play a really important role in maintaining goal-directed behaviour against sensory and emotional distractions (Wilmer & Chein, 2016). So in my third research, I aimed to examine the relationship between higher cognitive and executive functions and ICT-control.

4.4. Third research – Cognitive background factors of ICT-control, the relationship between cognitive control, inhibition, working memory, fluid intelligence and ICT-control with college students

4.4.1. Methods

My research issue in this research was the following: What is the relationship between ICT-control and particular cognitive background factors (like fluid intelligence, working memory and executive functions)?

The participants were college students (N=89, mean age: 20,83, standard deviation: 3,03). However, when I made the statistical analysis, I had to exclude one or two people in each investigation, because they had a really high error rate, so it was probable that these students did not consider their answers in the cognitive tests properly. So I excluded from the statistical analysis those whose error rate was three standard deviations over the mean error rate.

I used the ICT-control questionnaire (Cronbach alfa: 0,801) and different cognitive tests. To measure intelligence, I applied the Raven Advanced Progressive Matrices, which is a nonverbal intelligence test and measures fluid intelligence. I used the paper-pencil version of this test.

I used three cognitive tests. The first and second were the Flanker task and the Stroop task, which are suitable for measuring executive functions, like attention control and inhibition of automated answer. In the Flanker task, the stimuli were letters. Participants had to decide which key belonged to the target letter as fast as they could (within a second) and without making too many errors. (If the target letters were H or K, they should press key „Q", if the target letters were S or C, they should press key „P"). In the right and left side of the target letter there were noise letters, the so-called flankers. There were eight noise conditions in the test (congruent distraction, stimulus-incongruent distraction, answer-incongruent distraction, distraction, where the noise contained three letters with similar characteristics to those of the target, and distraction, where the noise contained three letters with dissimilar characteristics to the target, and three other noise conditions, where distances of the flankers from the target letter changed). There were also two nonoise conditions in the test where only the target letters were on the screen without any noise letters. In the Stroop task, stimuli were colour words written in colours, and participants had to indicate the colour of the word (not the meaning) as fast as they could and without making too many errors. In congruent trials the colour word and the colour it represented were the same. In incongruent trials the colour word and the colour it was presented in were not the same. In control trials, there were no colour words, just coloured rectangles. If the colour was red, they had to press key „D", if it was green, key „F", if it was blue, key „J" and if it was black, key „K".

Finally, I used a working memory measurement test, the N-back task. In this test, participants are presented with a sequence of stimuli and they have to decide whether the current stimulus on the screen matches the one n steps earlier in the sequence (n varied between 1 and 3). The working memory has an important role in performing this task, because participants have to keep the sequence of letters in their memory, while they have to decide, whether they saw the current letter on the screen n steps earlier or not (so to solve this problem, simultaneous storage and processing are required). As the level of the task is increasing, the cognitive load is increasing too, so the task will be harder and harder. If the participant gives an answer to a target letter, it is a hit, if the subject gives an answer to another stimulus (which is not the target), it is false alarm.

Participants completed the cognitive tests and the questionnaire in two sections. First, they filled in the intelligence test in groups, and then they did the three cognitive tests and the questionnaire individually. The tests in the second section were computerized (they ran in Inquisit), and the sequence of these tests were the same in each case; the first one was the Flanker, the second was the Stroop, and last one was the N-back task. Half of the participants filled in the ICT-control questionnaire first, half of them after the three computerized tests. Each subject chose a code number, they used this code in each measurement, so with these codes, I could link the data of the same participants in different measurements. In the last statistical table, I gave another code to every participant (a number between 1 and 89). The data collection lasted between February and May 2018.

4.4.2. Results and conclusions

I found no relationship between intelligence point and ICT-control; consequently, intellectual ability does not impact controlled ICT-use. Controlled ICT-use can reduce the negative impacts of ICT-use in the studying process. Some recent research has found similar results: the intellectual ability cannot modify the negative impacts of classroom internet-use on the learning performance, so intellectual ability cannot contribute to effective multitasking (however in this study, intellectual ability was not measured with an intelligence test) (Ravizza, Hambrick, & Fenn, 2014).

I also investigated the relationship between ICT-control and performance and response latency in cognitive tests. I found significant positive correlations between ICT-control and error rate in each of the noise conditions in the Flanker task (except congruent situations). People with uncontrolled ICT-usage were distracted by the noise letters in every situation, except where the noise letters were the same as the target letter. Of nonoise conditions, it was in the blocked situation (where only the target letter was on the screen without any noise letters in the whole block) where there was a significant relationship between ICT-control and error rate. Examining the response latency of the right answers, I found no relationships between ICT-control and response latency, except the congruent noise condition and blocked nonoise condition. It means that in these situations, response latency increased in the case of uncontrolled ICT-usage, and in other situations, there was no relationship between the RL and ICT-control. So it is possible that the reason for the worse performance of people with uncontrolled ICT-usage in noise conditions is not their bigger impulsivity, because higher impulsivity would have triggered faster response latencies.

In the Stroop task, I found no relationship between the rate of correct answers and ICT-control in any of the situations, and I found no relationship between ICT-control and response latencies, either. The question is what the reason can be for such different results in the two cognitive tests measuring the same field. I assumed that the reason could be that, by having to do the tasks in a very short time (within one second), the Flanker test required more strenuous efforts of the research subjects. In contrast, in the Stroop task, participants had unlimited time to answer (however, the instruction was that they should answer as fast as they could). (Therefore I investigated the difference between the response latencies in the two tests, and I found a really significant difference; in the Stroop task, there were higher response latencies). It follows from this that, due to the restricted time to answer, the Flanker task meant a higher cognitive load in the work memory, since participants did not have enough time to consider their answers, or to view the help on the top of the screen, instead, they had to keep the instruction in their memory.

According to some research results, the worse performance in an executive control task may have several possible reasons: people may have difficulty keeping the instruction in their working memory, or recalling it from the long-term memory (Shipstead, Harrison, & Engle, 2015). It can be the explanation for why people with uncontrolled ICT-usage performed worse in the blocked nonoise conditions despite the fact that their response latency in this condition did not decrease. It is possible that people with uncontrolled ICT-usage have difficulty ignoring distractions in the case of a higher cognitive load, so this could be in the background of the worse performance of people with uncontrolled ICT-usage in noise conditions. The results of a former study can confirm this possible explanation. The researchers of this study presumed that performance in an attention control test did not necessarily depend on the ability to focus on the particular task goal (i.e. not necessarily on attention control). They pointed out that the performance in these tests could depend on the skill of the active maintenance of the task instructions in the memory in the situations where the distractive, irrelevant or incongruent stimuli could distract our attention from our actual task. So the ability of maintaining task-relevant components in an active form in our memory (i.e. the functioning of the storage component of the working memory) is essential for the attention control skill, especially when there are some distracters, i.e. in the situations involving a high cognitive load. In such situations, distracters can displace things that ought to be remembered from the memory. Thus, the individual differences in storage capacity can be responsible for the attention control performance in response to a distracting environment (Chuderski, Taraday, Edward, & Smolen, 2012).

I found a significant negative correlation between uncontrolled ICT-usage and accuracy in the N-back task, however, when I investigated the accuracy in each level of the working memory task, I only found this relationship at the highest level (three-back). Consequently, this result can confirm the assumption that people with uncontrolled ICT-usage perform worse in situations requiring a high cognitive load. Besides, I found differences between controlled and uncontrolled ICT-usage in the number of hits (there were lower hit numbers in the case of uncontrolled ICT-usage), but there were no differences between these groups in the number of false alarms. So probably it is not the higher impulsivity that causes lower accuracy in the N-back task, since higher impulsivity should raise false alarm rate rather than decrease the hit rate. It is a remarkable result that, while ICT-control had a relationship with working memory accuracy, it was not related to fluid intelligence, although working memory and fluid intelligence are strongly related to each other. So probably ICT-control is connected with the individual variance of the working memory, not common with the fluid intelligence.

Results of the research in the relationship between working memory and fluid intelligence are heterogeneous. Researchers agree that there is a strong relationship between working memory and fluid intelligence, but they have different opinions of what causes this relationship: the storage or the processing component of the working memory. Based on the special literature, two possibilities can be mentioned, one of them being that attention control or executive functions are responsible for the relationship between working memory and fluid intelligence. Hence, even if the storage component of the working memory shows a correlation with the fluid intelligence, it does so because of the storage task, which requires too much cognitive load, therefore attention control processes are also included in the solution (Engle, Tuholski, Laughlin, & Conway, 1999). The other possibility is that the primary determinant of the working memory-fluid intelligence relationship is the storage component. In this case attention control is also determined by storage capacity; the higher the storage capacity, the easier the attention control task for the person in the presence of distractions (Chuderski et al., 2012).

Considering the results of the cognitive tests, we can draw the conclusion that ICT-control probably has a strong relationship with the storage component of working memory, and this storage component leads to a decrease in performance in situations requiring a higher cognitive load. If it is true, we can assume that, in case of a lower cognitive load, (i.e. at the lower levels of N-back), the relationship between ICT-control and accuracy in N-back diminishes or disappears, since in situations where cognitive load is lower, people with uncontrolled ICT-usage manage to store the required information better. If we investigate the correlations between ICT-control and accuracy at the different N-back levels, we can see that there is a significant negative relationship between these variables only at the three-back level.

5. General conclusions, the significance of research

All in all, we can conclude that uncontrolled ICT-usage goes with higher impulsivity and sensory seeking. Consequently, activities that disturb learning are more typical of such people (reducing boredom, relaxation with the device and social media use). So is intensive smartphone use (which goes with the appearance of automated checking habits, and the control of such habits is really difficult). Moreover, due to the deficit of the storage component of the working memory, and due to the weakness of the short-term memory, people with external ICT-control have worse performance in the case of increased working memory load. It is also worthy of note that multitasking, especially multitasking during the learning process, can require an increased working memory load.

In the light of the results, we can draw certain conclusions concerning the goal of education. ICT-use during learning can diminish the learning performance, but this effect depends on other factors, too. The effect is influenced by the way the secondary ICT-task appears besides the primary learning task. Full prohibition of ICT-use during learning is not the best option for a long term (Newell, 2015), so it would be important to teach the adaptive ICT-usage habits in an implicit way, as well as to inform students about the negative impacts of such activities in an explicit way, together with the appropriate explicit rules (Barry, Murphy, & Drew, 2015). Developing the skill of self-directed learning, particularly that of metacognitive skills becomes important, which makes it possible for students to be able to determine the costs of task-shifting in a given point of time, as well as to direct the timing and duration of the secondary task. For this purpose, it is also important to develop executive functions like attention control, which allows maintaining conscious attention focus. With the help of the executive function, the internal and external cues and automated habits cannot distract our attention so easily from our primary task.

It is important to highlight the age differences in this field, since executive functions are less developed with younger children, so the skill of conscious control is at lower levels with younger students (Rothbart & Posner, 2015). The neural network of children is excessively plastic, environmental effects can modify it easily. In contrast of the views of technological pessimists, not only the negative impacts of ICT-devices can have effects on their plastic nervous system, children can also experience the controlled, adaptive ICT-use, which can result in the fact that the ideas represented by biological optimists may be justified; our biological systems adapt to the use of modern devices. For this purpose, however, it is necessary to teach the strategies and techniques (preferably in an implicit way, embedded in curricula) that help the optimum use of ICT-devices for (and during) the learning process.

6. Limitations of the interpretation of the results, further research directions

The measuring tools applied in the presented investigations may be subject to criticism. There is a need for linguistic and content revision and clarification of the ICT-control questionnaire. Questionnaires are usually criticised for the fact that they do not measure the constructs directly, but through the perceptions of participants. It can be particularly true in the field of ICT-use, because in some cases people cannot judge the degree of their own ICT-use correctly. The three computerized cognitive tests can be criticised for requiring great efforts of research subjects, so it would probably have been more practical to do these tests in two sections. In these cognitive tests, I also found strong ceiling effects, which can modify the results to some extent. I found that ceiling effects probably reduced the extent of the correlations between the variables. So in further research it will be important to consider the above mentioned criticism.

Due to the correlational nature of the research, it is not suitable for drawing causal conclusions. Therefore, it would be worth carrying out long-term, longitudinal research in the future, in order to explore the causal links between the investigated variables.

In future studies, it would also be worth measuring the characteristics of ICT-use and the relationship between ICT-use and cognitive factors with younger children, since few studies of this kind have been done so far with the youngest.

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