Trends in Neuroscience and Education 5 (2016) 30–33

Contents lists available at ScienceDirect

Trends in Neuroscience and Education

journal homepage: www.elsevier.com/locate/tine

Research paper

Being physically active versus watching physical activity – Effects on inhibitory control

Markus Wolfgang Hermann Spitzer *, Marco Furtner

University of Innsbruck, Austria

ARTICLE INFO

Article history:
Received 16 February 2016
Received in revised form
18 February 2016
Accepted 18 February 2016
Available online 24 February 2016

Keywords:
Physical activity
Inhibitory control
Television
Children and adolescents
Flanker task

ABSTRACT

A comparison between the effects of the same type of physical activity being executed and watched on television on inhibitory control, the ability to focus on the relevant stimuli and disregard distraction, does not exist so far. Trying to close this gap, we tested 24 students on their inhibition control with the Erickson flanker task before and after a basketball session and a watching basketball on TV session, for 30 min respectively, in a within subjects cross-over design.

Reaction times significantly decreased in the incongruent condition after being physically active but not after watching physical activity. Subtracting the post-test mean reaction times from the pre-test mean reaction times, pre-post test differences are significantly higher for the physical activity group for the incongruent condition and indicate enlarged inhibitory control after physical activity. These results show that physical activity, in comparison to watching TV, has a positive effect on inhibitory control.

1. Introduction

There are many opportunities for children and adolescents in industrialized countries to carve out leisure time. When choosing between activities like watching TV, or working out, specific effects of such activities on cognition are hardly considered. However, various leisure activities may affect children's and adolescents' cognition for the better or worse.

Considering physical activity, there is a growing body of research relating aerobic fitness with cognitive health [7,8,9,10,14,21,22,38], higher socioeconomic status (SES) later in life [1], and academic achievement [4,12,37]. Even after a single bout of moderate-intensity physical activity (between 20 and 40 min) positive effects on certain types of cognition have been found [39]. In particular, the function of cognitive control is positively affected by an acute bout of physical activity in children and adolescents.

The concept of cognitive control consists of three different components known as working memory, cognitive flexibility, and inhibitory control. Here, we focus on the inhibitory control component-the ability to focus on the relevant and goal-directed stimuli and disregard distractions that may influence decision making and responding [20]. The flanker task can be used to measure inhibitory control [26]. The task varies the amount of inhibitory control by having participants' focus and respond to a central stimulus surrounded by other stimuli. These surrounding stimuli can either be congruent or incongruent with the response to the central stimulus. Therefore, more inhibitory control is needed to respond in the incongruent condition. Reaction time (RT) and task accuracy are recorded, with high accuracy and/or short RT indicating superior inhibitory control.

Using the flanker task, Hillman et al. [26], and O'Leary et al. [33] conducted two separate within-subject studies to examine whether changes in inhibitory control can be found after a single bout of moderate-intensity physical activity, when compared to a sedentary control condition.

In children (mean age 9.5 years; SD 0.5 years) 20 min of physical activity of moderate-intensity caused more accurate performance in the flanker task, with fewer errors in the incongruent condition [27]. However, reaction time did not differ between conditions. O'Leary et al. [33] examined undergraduate students (mean age 21.2 years; SD 1.5 years) with a similar study design, and added two more control conditions: an exergaming condition and a videogame condition. Results showed decreases in reaction times after the moderate-intensity physical activity session but not after any of the other three control sessions. In this study, task accuracy did not vary significantly between conditions. Together, these studies indicate that moderate-intensity acute bouts of physical activity can enhance cognitive functions, in particular inhibitory control.

However, increasing screen time in today's young society leads to more sedentary behavior and less physical activity. In fact, the prevalence of overweight and obese children and adolescents has risen during the last decade, in parallel to a media consumption time increase [3,5,11,22,23,24,30,31,34]. Furthermore, physical

* Corresponding author.
E-mail address: Markus.Spitzer@student.uibk.ac.at (M.W.H. Spitzer).

http://dx.doi.org/10.1016/j.tine.2016.02.003
2211-9493/

activity is not considered a serious subject by most schooling systems [20], whereas there is a trend for media-education to be added to the curriculum [25].

Previous studies showed different effects of television-viewing, in comparison to physical activity, on inhibitory control. First, the risk of children developing a decreased attention span increases with the amount of time spent in front of TV [13,35]. Secondly, adolescents (age 14) watching more than 1 h of television per day, show a higher risk of poor grades and long-term academic failure [28]. Thirdly, adolescents (age 14) viewing more than 3 h of television a day have an elevated risk of subsequent attentional problems and are the least likely to continue on to (or even complete) postsecondary education [28]. Considering acute bouts of single television viewing, Lillard et al. found inhibitory control to be decreased after watching a fast paced video, but not after a slow paced video, for 9 min. This study shows that, depending on the type of the TV program watched, acute effects of TV on inhibitory control can differ in having no or negative effects.

Thus, it is important to understand how physical activity and sedentary screen time influence cognition differently. To minimize confounds, such as emotions, planning, enjoyment, and other sport-related psychological processes, we had subjects play and watch (on a TV screen) the same type of physical activity (basketball). To our understanding, the effects of physical activity and watching the very same activity on TV on inhibitory control, have not been compared yet. Furthermore, previous studies examined the effects of aerobic fitness or physical activity on cognition in groups of narrow age ranges, i.e., older adults [21], adolescents [26], and children [27,33]. In contrast this study investigates subjects from 10 to 18 years of age. Little is known about the acute effects of a single bout of physical activity compared to watching similar TV content for the same time on cognition, especially on cognitive control.

Taking the results from physical activity and TV together, we ask whether children's and adolescents' inhibitory control is influenced differently under these two conditions. Students completed a modified Eriksen flanker task before and after either playing or watching basketball. We hypothesized that after the basketball session of 30 min children and adolescents show greater inhibitory control in comparison to the watching basketball on TV session, as reflected in reduced reaction times and increased task accuracy.

2. Methods

2.1. Participants

24 German students (age: 13–18; mean age: 14.8; 3 girls, 21 boys) were recruited by newspaper advertisement and received a free three hour long basketball practice for their participation the day after the intervention was completed. All data of the 24 students were analyzed. Children volunteered for participation after an informative meeting. Written informed consent according to the Declaration of Helsinki was obtained from the children's parents.

2.2. Procedure

On two consecutive days students participated in a modified version of the Erickson flanker task at 9 a.m. in the morning. Afterwards on the first day, eleven participants went to have a 30 min basketball practice session. The other thirteen participants watched a basketball highlight movie. After both 30 min sessions all 24 students underwent the modified flanker task again. On the very next day both groups switched their sessions and underwent the flanker task, before and after their sessions, again.

The test was conducted in a school in two class rooms (one class room for watching basketball and the other one for undertaking the modified flanker task) and one gym. The gym was located close to the two class rooms which indicated that there was no difference in walking time from the testing room to the gym or to the other class room. While watching basketball on TV all subjects were seated. The basketball program contained many dribbling and shooting drills. In addition, all subjects were motivated to move a lot and to be physically active for the whole session.

During the flanker task participants have to detect whether a small square is colored blue or red. Two big squares are next to the small square, again in blue or red color. With their two forefingers (left and right hand) subjects have to respond as quickly as possible which color the small square has, using the right or left mouse buttons. The RT and task accuracy is measured by the laptop. The flanker task measures two conditions. The response to a congruent set of squares e.g. all squares are blue or red, and the incongruent set of squares, e.g. a small red square is surrounded by two big blue squares and vice versa.

For the incongruent condition, when participants disregard the two bigger and other colored distracting squares more inhibitory control resources are needed for selecting the right answer in comparison to congruent trials. We analyzed task accuracy and RTs of all correct responses.

As a measure of inhibitory control we subtracted the correctly responded pre-test means' RT from the correctly responded post-test means' RT of the incongruent and congruent condition respectively. An increase in the difference between pre-test and post-test RT is indicating enrichment in inhibitory control.

We examined the pre–post differences and task accuracy before and after playing basketball and watching basketball on TV for 30 min. A two factorial within-subject design, with pre/post and playing/watching as factors was conducted with MATLAB.

3. Results

A repeated measure analysis of variance (ANOVA) on pre-test RT minus post-test RT with the within-subject factors incongruent/congruent and playing/viewing, showed no significant main effect (F (1, 23)=5.1328, p=0.332), but a significant interaction. Only for the incongruent condition and when physical activity was executed for 30 min, the difference in pre-test minus post-test RT increased significantly (see Fig. 1 and Table 1; mean RT pre–post incongruent condition basketball: 45.0 ms; mean RT pre–post incongruent condition viewing basketball: 12.6 ms; p=0.0017), with lower RT at post-test in comparison to the TV group. This difference was not found for the congruent condition (mean pre–post congruent condition playing basketball: 26.3 ms; mean pre–post congruent condition watching basketball on TV: 18.2 ms; p=0.3037).

Taking a closer look at the mean RTs we conducted another ANOVA with the factors pre-test/post-test, incongruent/congruent and playing/viewing (see Table 2). Here, in the incongruent condition we found a significant decrease in RT after physical activity was executed ($p < 0.001$), but not after participants watched physical activity on TV (p=0.07), indicating that inhibitory control increased after 30 min of physical activity but not after 30 min of watching TV. However, in the congruent condition both groups RTs decreased significantly (basketball group: $p < 0.001$; TV group: $p < 0.05$). At baseline the RT of the basketball and the TV group did not differ in the incongruent condition (p=0.12), and the congruent condition (p=0.36).

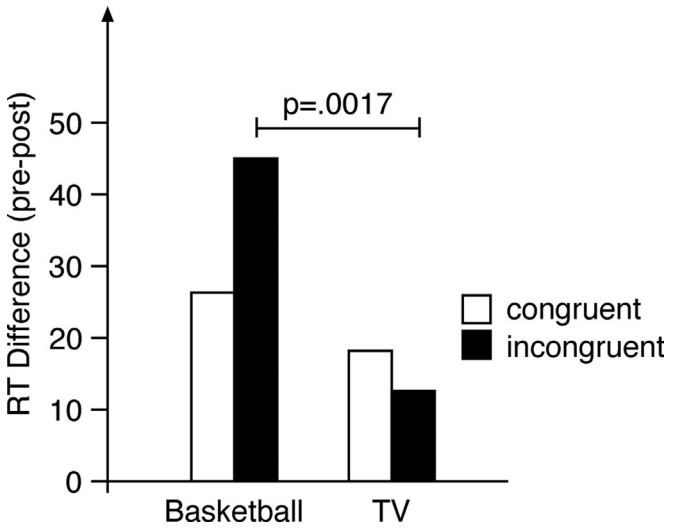

Fig. 1. Difference in reaction time (RT) in the Eriksen flanker task (pre minus post) performed before and after either playing basketball or watching basketball on TV. In the congruent condition (white columns), these differences were not significantly different, whereas in the incongruent task, the differences were highly significantly different (significant interaction effect in the ANOVA).

Table 1
Post-hoc test of the ANOVA.

Group	Condition	1) 26.3 ms	2) 45.0 ms	3) 18.2 ms	4) 12.6 ms
1) Basketball	Congruent		*p=0.022*	*p=0.304*	*p=0.195*
2) Basketball	Incongruent	*p=0.022*		*p=0.005*	*p=0.002*
3) TV	Congruent	*p=0.304*	*p=0.005*		*p=0.467*
4) TV	Incongruent	*p=0.195*	*p=0.002*	*p=0.467*	

Note: pre-test minus post-test mean RT values are listed in the upper row.

4. Discussion

Physical activity enhanced inhibitory control in a group of 10–18 year olds. Comparing the physical activity condition with the TV condition, mean RTs for incongruent trials significantly decreased at post-test, which led to a larger pre–post test difference for the incongruent condition for the physical activity group. This RT difference is significantly higher in comparison to pre–post test differences for incongruent trials for the TV group, and indicates improvements in inhibitory control after physical activity only.

In addition, at baseline, children's flanker task results did not differ. After a single bout of 30 min moderate-intensity physical activity, mean RTs were significantly faster for incongruent condition, with no differences in task accuracy.

These pre–post test RT changes, in the incongruent condition show that the students were able to focus on the relevant stimuli and disregarded the two distracting flankers better, after physical activity was executed but not after they watched TV. The significant increase in pre-test minus post-test RT and the significant decrease in RT at post-test, for the incongruent condition and the physical activity group, indicate an increased inhibitory control. This effect was not observed after children and adolescents watched TV. Thus, our results support the idea that physical activity leads to improvements in inhibitory control, whereas watching TV does not.

Inhibitory control (i.e. staying focused on the relevant actions and disregarding distractions) is required every day and develops during childhood [17,20]. Especially when challenged in younger age [16], inhibitory control can be trained [20], and thus inhibitory control capacity can be enhanced. Furthermore, inhibitory control is a predictor of higher academic achievement and higher SES later in life [15,27]. Thus, expanding children's and adolescents inhibitory control capacity should be one of the main goals of the educational system.

Looking at real life benefits of physical activity in a longitudinal study, Spitzer and Hollmann [37] found that children being more physically active, report superior school grades in Math and German language.

Other longitudinal studies, using functional MRI, found changes in neuronal activation while performing a flanker task in the prefrontal cortex (PFC) in children who passed through a physical activity program, compared to a sedentary control group [9].

As regards the mechanism of action, Hillman and colleagues examined children's performance on the flanker task in conjunction with electroencephalography (EEG) measures. Results showed larger P300 amplitude (i.e., increased allocation of attention) and a shorter latency (i.e., increased processing speed) after physical activity, while performing a flanker task, compared to rest. Especially, for incongruent trials requiring more inhibitory control, young adults showed increased P300 amplitudes, after the physical activity session, but not after the resting session. The authors suggest that physical activity increases allocation of attention and shorter processing time and notes that "[…] acute exercise may serve as a viable treatment for enhancing cognitive function […]" [27].

However, children and adolescents in westernized countries are becoming increasingly sedentary and unfit [2,3,18,32,40]. One of the causes is the increasing time spent in front of TV. This shift is accompanied by increasing prevalence's of chronic physical health problems such as obesity and type-2 diabetes [3,5,6,11,19,23,24,30,31,34]. Furthermore, mental health of children may be compromised, as increasing time spent in front of TV is associated with an increasing risk of children to develop attentional problems [13,29,36]. In our study, watching physical activity on TV for 30 min had no negative effects on children's and adolescents' inhibitory control. But the content of the video watched was rather slow than fast paced, and Lillard [29] suggests that, whether watching TV has negative or no effects on inhibitory control, is content dependent. The study is limited in several ways. Individual aerobic fitness levels of children and adolescents were

Table 2
Post-hoc test of the ANOVA.

Group	Pre/post	Condition	1) 498 ms	2) 521 ms	3) 472 ms	4) 476 ms	5) 506 ms	6) 513 ms	7) 487 ms	8) 500 ms
1) Basketball	Pre	Congruent		$p=0.002$	$p<0.001$	$p=0.002$	$p=0.362$	$p=0.050$	$p=0.058$	$p=0.677$
2) Basketball	Pre		$p=0.002$		$p<0.001$	$p<0.001$	$p=0.018$	$p=0.122$	0.0001	$p=0.003$
3) Basketball	Post	Congruent	$p<0.001$	$p<0.001$		$p=0.383$	$p<0.001$	$p<0.001$	$p=0.022$	$p<0.001$
4) Basketball	Post	Incongruent	$p=0.002$	$p<0.001$	$p=0.383$		$p<0.001$	$p<0.001$	$p=0.059$	$p=0.001$
5) TV	Pre	Congruent	$p=0.362$	$p=0.018$	$p<0.001$	$p<0.001$		$p=0.183$	$p=0.012$	$p=0.343$
6) TV	Pre	Incongruent	$p=0.050$	$p=0.122$	$p<0.001$	$p<0.001$	$p=0.183$		$p=0.0008$	$p=0.070$
7) TV	Post	Congruent	$p=0.058$	$P<0.001$	$p=0.022$	$p=0.059$	$p=0.013$	$p=0.0008$		$p=0.060$
8) TV	Post	Incongruent	$p=0.677$	$p=0.003$	$p<0.001$	0.0012	0.343	$p=0.070$	$p=0.060$	

Note: reaction time values are listed in the upper row.

not tested before the study. Thus, it remains unclear whether most of the children and adolescents were at the same aerobic fitness level or not. In addition, previous studies focused on one age group, and reported changes in task accuracy in children [27]. We studied subjects of a broad age range, such that differences in speed accuracy trade off related to age may be causing the differences between our results and the results of previous studies. It is known that inhibitory control is age related, so task performance (and speed accuracy tradeoffs) could vary between individuals of different age. We did not examine whether playing sports using a sports video game differs from just watching sports on screen. Further studies should be conducted considering this research question.

We conclude that parents should consider different consequences of the out of school activities, their children are involved in. In sum, this is the first study examining the same type of physical activity (basketball) virtually and in real life, indicating that children benefit significantly more when physical activity is executed than watched on TV.

Acknowledgments

We are grateful to Laura Chaddock-Heyman and Arthur Kramer for the guidance and comments on the manuscript.

References

[1] M.A.I. Aberg, N.L. Pedersen, K. Toren, M. Svartengren, B. Bäckstrand, T. Johnsson, C.M. Cooper-Kuhn, D. Aberg, M. Nilsson, H.G. Kuhn, Cardiovascular fitness is associated with cognition in young adulthood, Proc. Natl. Acad. Sci. USA 106 (2009) 20906–20911.
[2] E. Atlantis, E.H. Barnes, M.A. Fiatarone Singh, Efficacy of exercise for treating overweight in children and adolescents: a systematic review, Int. J. Obes. 30 (2006) 1027–1040.
[3] J.L. Baker, L.W. Olsen, T.I.A. Sorensen, Childhood body-mass index and risk of coronary heart disease in adulthood, New Engl. J. Med. 357 (23) (2007) 2329–2337.
[4] D.M. Castelli, C.H. Hillman, S.M. Buck, H.E. Erwin, Physical fitness and academic achievement in third- and fifth-grade students, J. Sport Exerc. Psychol. 29 (2007) 239–252.
[5] A. Cattaneo, L. Monasta, E. Stamatakis, S. Lioret, K. Castetbon, F. Frenken, Y. Manios, G. Moschonis, S. Savva, A. Zaborskis, A.I. Rito, M. Nanu, J. Vignerová, M. Caroli, J. Ludvigsson, F.S. Koch, L. Serra-Majem, L. Szponar, F. van Lenthe, J. Brug, Overweight and obesity in infants and pre-school children in the European Union: a review of existing data, Obes. Rev. 11 (2010) 389–398.
[6] S. Chinn, R. Rona, Prevalence and trends in overweight and obesity in three cross sectional studies of British children 1974–94, BMJ 322 (2001) 24–26.
[7] V.R. Chomitz, M.M. Slining, R.J. McGowan, S.E. Mitchell, G.F. Dawson, K. A. Hacker, Is there a relationship between physical fitness and academic achievement? positive results from public school children in the northeastern United States, J. Sch. Health 79 (2009) 30–37.
[8] L. Chaddock, K. Erickson, R. Prakash, J.S. Kim, M. Voss, M. VanPatter, M. Pontifex, L. Raine, A. Konkel, C. Hillman, N. Cohen, A.F. Kramer, A neuroimaging investigation of the association between aerobic fitness, hippocampal volume, and memory performance in preadolescent children, Brain Res. 1358 (2010) 172–183.
[9] L. Chaddock, K. Erickson, R. Prakash, J.S. Kim, M. Voss, M. VanPatter, M. Pontifex, L. Raine, A. Konkel, C. Hillman, N. Cohen, A.F. Kramer, A neuroimaging investigation of the association between aerobic fitness, hippocampal volume, and memory performance in preadolescent children, Brain Res. 1358 (2010) 172–183.
[10] L. Chaddock, C.H. Hillman, M.B. Pontifex, C.R. Johnson, L.B. Raine, A.F. Kramer, Childhood aerobic fitness predicts cognitive performance one year later, J. Sports Sci. 30 (5) (2012) 421-420.
[11] L. Chaddock-Heyman, K.I. Erickson, M.W. Voss, A.M. Knecht, M.B. Pontifex,, D. M. Castelli, C.H. Hillman, A.F. Kramer, The effects of physical activity on functional MRI activation associated with cognitive control in children: a randomized controlled intervention, Front. Hum. Neurosci. 7 (72) (2013) 1–13.
[12] L. Chaddock-Heyman, K.I. Erickson, M.W. Voss, J.P. Powers, A.M. Knecht, C. H. Hillman, A.F. Kramer, White matter microstructure is associated with cognitive control in children, Biol. Psychol. 94 (2013) 100–115.
[13] Y.K. Chang, J.D. Labban, J.I. Gapin, J.L. Etnier, The effects of acute exercise on cognitive performance: a meta-analysis, Brainresearch 1453 (2012) 87–101.
[14] D.A. Christakis, F.J. Zimmerman, D.L. DiGiuseppe, C.A. McCarty, Early television exposure and subsequent attentional problems in children, Pediatrics 113 (4) (2004) 708–713.
[15] S.J. Colcombe, A.F. Kramer, Fitness effects on the cognitive function of older adults: a meta-analytic study, Psychol. Sci. 14 (2003) 125–130.
[16] J.T. Coldren, Cognitive control predicts academic achievement in kindergarten children, Mind Brain Educ. 7 (1) (2013) 40–48.
[17] E. Dahlin, L. Nyberg, L. Bäckman, A.S. Neely, Plasticity of executive functioning in young and older adults: immediate training gains, transfer, and long-term maintenance, Psychol. Aging 23 (2008) 720–730.
[18] M.C. Davidson, D. Amso, L.C. Anderson, A. Diamond, Development of cognitive control and executive functions from 4 to 13 years: evidence from manipulations of memory, inhibition, and task switching, Neuropsychologia 44 (11) (2006) 2037–2078.
[19] Department of Health Services Human, Department of Education. Promoting better health for young people through physical activity and sports. A Report to the President from the Secretary of Health and Human Services and the Secretary of Education. Centers for Disease Control, Silver Spring, 2000.
[20] A. Diamond, W.S. Barnett, J. Thomas, S. Munro, Preschool program Improves cognitive control, Science 318 (5855) (2007) 1387–1388.
[21] A. Diamond, K. Lee, Interventions shown to aid executive function development in children 4–12 years old, Science 333 (2011) 959–964.
[22] K.I. Erickson, M.W. Voss, R.S. Prakash, Exercise training increases size of hippocampus and improves memory, Proc. Natl. Acad. Sci. USA 108 (7) (2011) 3017–3022.
[23] C. Frye, J. Heinrich, Trends and predictors of overweight and obesity in East German children, Int. Journal. Obes. 27 (2003) 963–969.
[24] S.L. Gortmaker, B.A. Swinburn, D. Levy, R. Carter, P.L. Mabry, D.T. Finegood, T. Huang, T. Marsh, M.L. Moodie, Changing the future of obesity: science, policy, and action, Lancet 378 (2011) 838–847.
[25] P.M. Greenfield, Mind and Media, Psychology Press, New York, 2014.
[26] C.H. Hillman, E.M. Snook, G.J. Jerome, Acute cardiovascular exercise and executive control function, Int. J. Psychophysiol. 48 (2003) 307–314.
[27] C.H. Hillman, S.M. Buck, J.R. Themanson, M.B. Pontifex, D.M. Castelli, Aerobic fitness and cognitive development: event-related brain potential and task performance indices of executive control in preadolescent children, Dev. Psychol. 45 (1) (2009) 114–129.
[28] J.G. Johnson, P. Cohen, S. Kasen, J.S. Brook, Extensive television viewing and the development of attention and learning difficulties during adolescence, Arch. Pediatr. Adolesc. Med. 161 (5) (2007) 480–486.
[29] A.S. Lillard, J. Peterson, The immediate impact of different types of television on young children's executive function, Pediatrics 128 (2011) 644–649.
[30] D.S. Ludwig, Childhood obesity: the shape of things to come, New Engl. J. Med. 357 (23) (2007) 2325–2327.
[31] L.A. Moreno, A. Sarríaa, J. Fleta, G. Rodríguez, J.M. Pérez Gonzáleza, M. Bueno, Sociodemographic factors and trends on overweight prevalence in children and adolescents in Aragón (Spain) from 1985 to 1995, J. Clin. Epidemiol. 54 (2001) 921–927.
[32] J.A. Mendoza, F.J. Zimmerman, D.A. Christakis, Television viewing, computer use, obesity, and adiposity in US preschool children, Int. J. Behav. Nutr. Phys. Act. 4 (2007) 44.
[33] K.C. O'Leary, M.B. Pontifex, M.R. Scudder, M.L. Brown, C.H. Hillman, The effects of single bouts of aerobic exercise, exergaming, and videogame play on cognitive control, Clin. Neurophysiol. 122 (2011) 1518–1525.
[34] V.J. Rideout, U.G. Foehr, D.F. Roberts. Media in the Lives of 8- to 18-Year-Olds. A Kaiser Family Foundation Study, 2010.
[35] M. Spitzer, Information technology in education: risks and side effects, Trends Neurosci. Educ. 3 (2014) 81–85.
[36] M. Spitzer, M-Learning? When it comes to learning, smartphones are a liability, not an asset, Trends Neurosci. Educ. 4 (2015) 87–89.
[37] U.S. Spitzer, W. Hollmann, Experimental observations of the effects of physical exercise on attention, academic and prosocial performance in school settings, Trends Neurosci. Educ. 2 (2013) 1–6.
[38] B.A. Sibley, J.L. Etnier, The relationship between physical activity and cognition in children: a meta-analysis, Pediatr. Exerc. Sci. 15 (2003) 243–256.
[39] P.D. Tomporowski, Effects of acute bouts of exercise on cognition, Acta Psychol. 112 (2003) 297–324.
[40] R.M. Viner, T.J. Cole, Television viewing in early childhood predicts adult body mass index, J. Pediatr. 147 (2005) 429–435.