TIME OF FAST LEARNING IN SPEED-ACCURACY TASKS IS DIFFERENT FOR CHILDREN AND ADULTS

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ABSTRACT

Research background and hypothesis. Motor learning is characterized by specific set of changes in performance parameters which occur gradually over a course of learning period.

Research aim. The aim of the study was to establish and compare the characteristics of learning speed-accuracy movements of children and adults.

Research methods. The research participants were 13 healthy boys, 16 girls, 5 healthy men and 7 women. The research was carried out applying the analyzer of dynamic parameters of human leg and arm movement (DPA-1). We registered maximal and average movement speed, the reaction time and the movement trajectory of the right hand.

Research results. We established significant differences ($p < 0.05–0.001$) in reaction time (RT), average movement speed (Va), maximal movement speed (Vm) and movement trajectory (S) between children and adults.

Discussion and conclusions. Motor adaptation in timescales of minutes is supported by two distinct processes: one process when a person learns slowly from errors but has strong retention, and another process is when a person learns rapidly from errors but has poor retention (Ethier et al., 2008). We might only speculate that children used the second strategy more than adults. The time of fast learning in a speed-accuracy task was different between children and adults. The accuracy was most improved by children at the expense of the quickness, while adults improved only the average velocity of their performance. Besides, most of the variability of performance variables changed more significantly in children than in adults.

Keywords: motor learning, motor control, age, manual task.

INTRODUCTION

Two categories of plastic neural changes in the brain have been established with learning motor skills: those that have focused on early rapid changes occurring over minutes (Karni et al., 1995; Shadmehr, Holcomb, 1997; Maquet et al., 2003; Penhune, Doyon, 2005), and on slowly developing changes occurring over days or weeks (Karni et al., 1995; Kleim et al., 2004; Rosenkranz et al., 2007; Ethier et al., 2008). The results of these studies have shown the involvement of specific regions of motor cortex, the cerebellum and basal ganglia depending of the stage of motor learning. It has been hypothesized that in the cerebellum, early learning is probably

mediated by error-correction mechanisms (Ito, 2001; Penhune, Doyon, 2005), while later it may involve plastic changes in regions of cerebellar hemispheres and / or the cerebellar nuclei specific to the effector and the internal mode for the task (Nezafat et al., 2001).

The acquisition of new motor skill follows two distinct stages with continued practice: first, there is an early, fast learning stage in which performance improves rapidly within a single training session; later, there is a slower learning stage with time period of several sessions of practice (Ungerleider et al., 2002). Motor learning is characterized by specific set of changes in performance parameters (Flament et al., 1999; Kempf et al., 2001). These changes occur gradually over a course of learning period. While the decreases or increases in these parameters have been documented in a variety of tasks, it remains to be determined whether the time course of fast learning is different between children and adults. Therefore the main aim of this study was to establish if there are differences in time course of reaction time, average and maximal velocity and trajectory as well as variability of these variables during 5 series of 20 repetitions in speed-accuracy task.

RESEARCH METHODS

The subjects. 13 healthy boys aged 6.73 ± 0.48 years, body mass – 25.50 ± 4.62 kg, body height – 125.07 ± 7.32 cm; and 16 girls aged 6.50 ± 0.51 years, body mass – 22.87 ± 3.60 kg, body height – 121.81 ± 4.05 cm; as well as 5 healthy men aged 24.60 ± 3.51 years, body mass – 77.01 ± 2.83 kg, body height – 181.80 ± 8.44 cm; and 7 women aged 22.47 ± 1.46 years, body mass – 58.11 ± 4.05 kg, body height – 167.55 ± 3.83 cm participated in the study. The subjects were informed about the course of the study.

Analyzer DPA-1 measuring dynamic parameters of human arm and leg motion. The analyzer contains two measuring devices connected to a stationary standard computer with *Windows* (or compatible to it) operating environment, which has an embedded measurement card with an operating system, and a 17' diameter screen. The measuring device includes the mechanism for transforming handle movement into the measurement zone reduced six times; the mechanism for measuring the coordinates of handle movement; the mechanism for establishing the horizontal component of the module of strength impacting the handle with the strength measuring element; the electromagnetic mechanism for the development of strength of programmable resistance; the strength measuring unit; the control unit of programmable resistance strength; and power supply.

Measuring devices are fastened to the support panel where the handle units slide on its surface. The power supply switches with the power voltage indicators are fitted in the front of the measuring devices, the connectors for the power cable and the distance control are built-in in the back.

Methods of studying motor learning. During the research the participants are seated in a special chair at the table with a DPA-1 fastened on it. The subject's back is straight and leant at the backrest. Both arms are bent 90^0 at the elbow joint so that the upper arms are nestled against the sides, and the forearms rest on the DPA-1 support panel. The position of the DPA-1 chair is regulated so that the subject could sit comfortably and take a standard position. The distance between the computer screen and the subject's eyes is approximately 0.7 m.

The participants perform the tests with their right arm. In accordance with the tasks of the test prepared in advance, a target – a red circle 0.007 m in diameter – appears on the screen at stated intervals. The distance from the start zone to the target is 0.16 m. The repeated trajectories of arm movements are identical. During each task the subject sets the handle symbol of 0.0035 m in diameter to the start zone (the center of a green circle the diameter of which is 0.01 m) on the computer screen. The program intermittently (every 1–3 s) generates a sound signal and / or a target in the certain place on the computer screen, and the subject has to react to it pushing the handle. The measurement cycle is completed after hitting the target with the circle of the handle symbol. The information about the task performed is stored in the computer memory and later it is transferred to *Microsoft Excel* program.

Motor learning research procedures. The subjects performed a complicated task. They had to react to the target on the computer screen as fast as they could and to push the handle of the device so that the circle of the handle symbol reached the target as fast as possible and followed the most accurate trajectory, and then stopped in it. The target appeared in the same place on the screen. The end-point of the movement was recorded when the center of the handle symbol stopped in the circle and stayed there for no less then 0.03 s. After explaining the task the subjects were allowed

to take three tries, the results of which were not recorded. Then the task was performed in five series, 20 repetitions in each of them. The interval between the series was 2 min, but the repetitions in one series were performed uninterruptedly. We registered maximal (Vm) and average (Va) movement speed, the reaction time (RT) and the movement trajectory (S) of the right hand. After each repetition the subjects could see their achieved result on the computer screen, besides they were motivated verbally to do their best.

Mathematical statistics. The two-way analysis of variance (ANOVA) for repeated measures was used to determine the effect of time (5 series) and age (children vs. adults) on different variables. The one-way analysis of variance (ANOVA) for repeated measures was used to determine the effect of time (5 series) on different variables. If significant effects were found, post hoc testing was performed applying paired t-tests with a Bonferroni correction for multiple comparisons. Descriptive data are presented as means ±SD. The level of significance was set at 0.05. In order to evaluate the relationship between changes in different variables Pearson's correlation coefficient was established. Based on alpha level of 0.01, the sample size (n = 20), standard deviations and the average level during the first and the fifth series, the statistical power was calculated for all mechanical indicators. Statistical power in all the cases was more than 80 per cent.

RESEARCH RESULTS

We established that there was a significant difference ($p < 0.05–0.001$) in RT, Va, Vm and S between children and adults (Fig. 1, 2, 3, 4). One-way ANOVA shows a significant effect of time (five series: quick learning) in Vm and S of children ($p < 0.01$) and in Va of adults ($p < 0.05$). There was a significant difference in the changes of Va, Vm and S between children and adults (Fig. 5). It is worth noting that S and Vm decreased significantly after the first series and did not change during the 2–5 series while Va increased gradually during all five series in adults.

Figures 6, 7, 8 and 9 show that the variability of all variables of children was significantly greater than that of adults. There were significant changes in the variability (CV) of Va, Vm and S in children, and in the variability of RT in adults. It should be noted that there was no significant difference in CV of Va and S between children and adults during the 2–5 series.

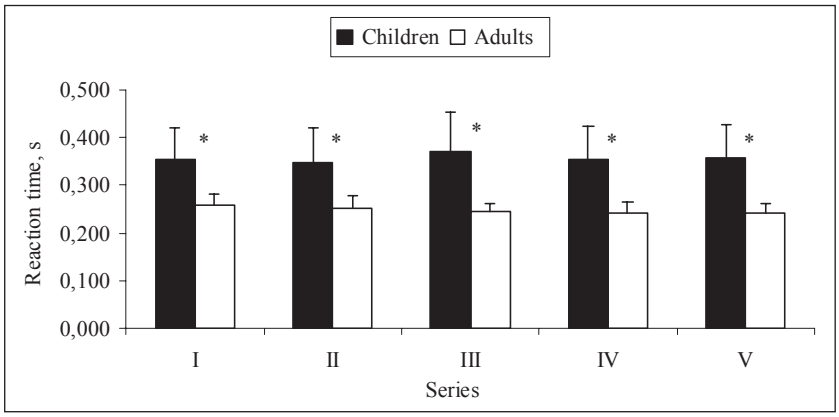


Figure 1. **Changes in reaction time (RT) of children and adults during 5 series of 20 repetitions in the speed-accuracy task**

Note. * – $p < 0.001$, between children and adults.

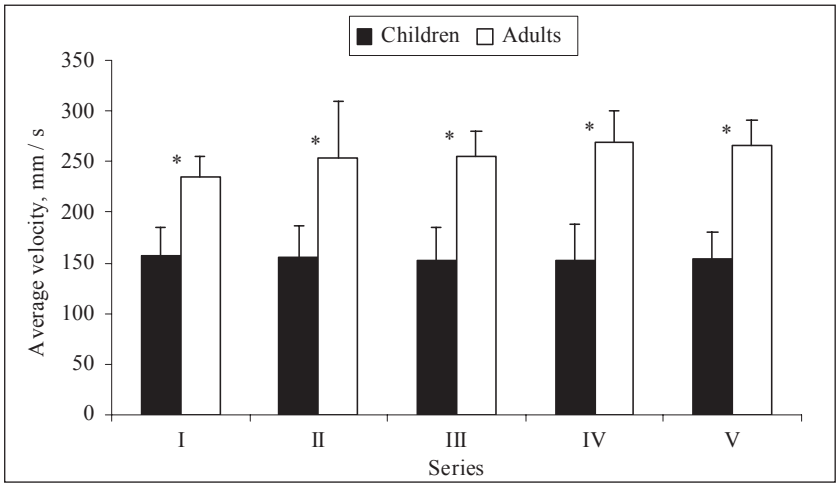
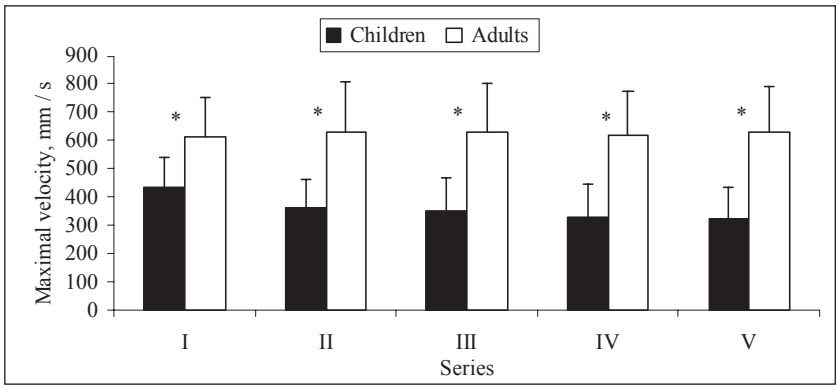


Figure 2**. Changes in average velocity (Va) of children and adults during 5 series of 20 repetitions of speed – accuracy task**

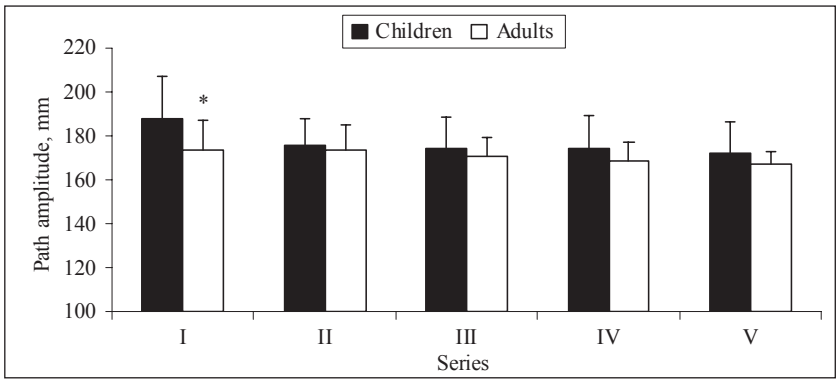
Note. * – $p < 0.001$, between children and adults.

Figure 3. **Changes in maximal velocity (Vm) of children and adults during 5 series of 20 repetitions of speed-accuracy task**



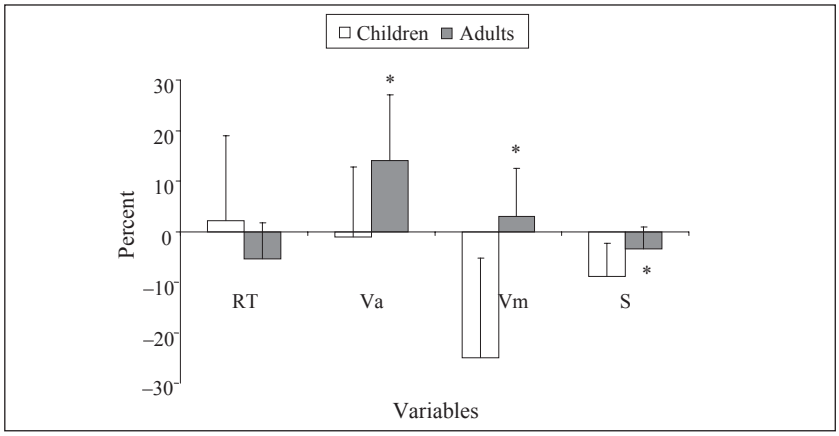
Note. * – $p < 0.001$ between children and adults.

Figure 4**. Changes in path amplitude (S) of children and adults during 5 series of 20 repetitions of speed – accuracy task**



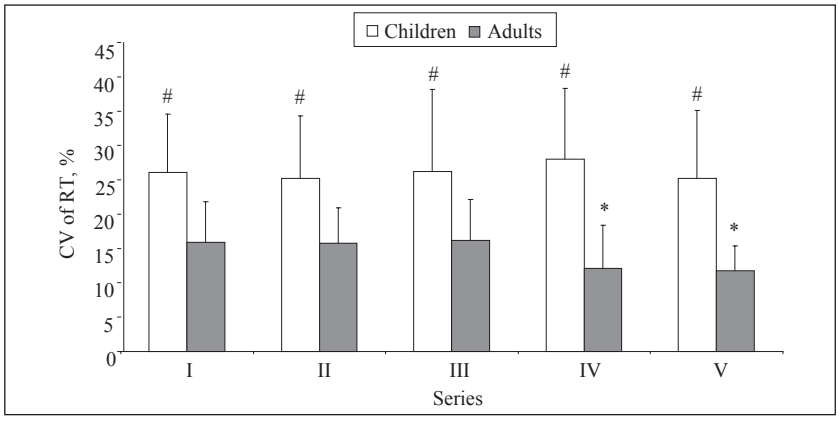
Note. * – $p < 0.05$ between children and adults.

Figure 5**. Changes in per cent of reaction time (RT), average velocity (Va), maximal velocity (Vm) and path amplitude (S) during 5 series of 20 repetitions of speed-accuracy task**



Note. $p < 0.05$ between children and adults.

Figure 6. **Changes in CV of reaction time (RT) of children and adults during 5 series of 20 repetitions of speed-accuracy task**



Note. # – $p < 0.001$ between children and adults; *– $p < 0.05$, compared to the first series.

We found a significant relationship between the changes in RT and Va of children and adults after five series, r = –0.62 and r = –0.68 respectively. Besides, there was a significant relationship between the changes in S and Vm in children after the second series (r = 0.49).

DISCUSSION

The time difference in the speed-accuracy task variables between children and adults. As far as we know, this is the first study to have shown that the time of fast learning in a speed –

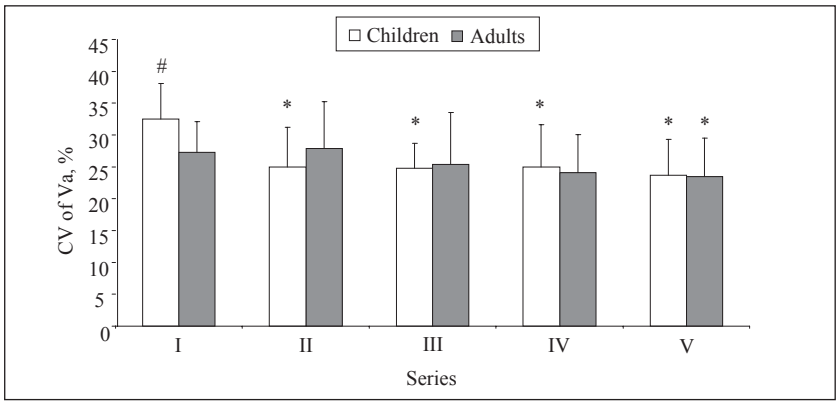


Figure 7. **Changes in CV of average velocity (Va) of children and adults during 5 series of 20 repetitions of speed-accuracy task**

Note. # – $p < 0.05$ between children and adults; * – $p < 0.05$, compared to the first series.

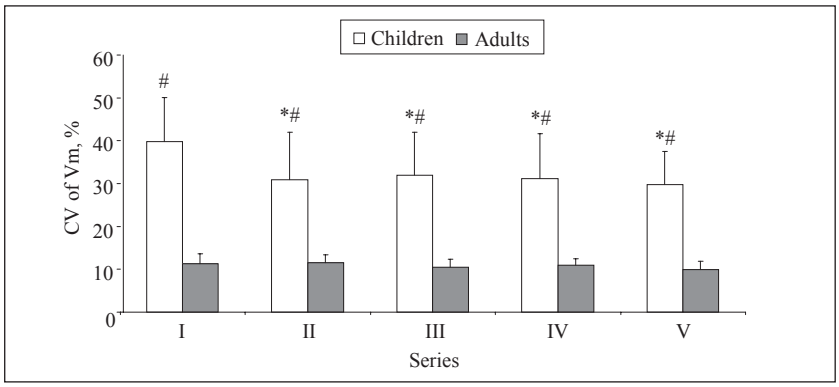


Figure 8. **Changes in CV of maximal velocity (Vm) of children and adults during 5 series of 20 repetitions in the speed-accuracy task**

Note. # – $p < 0.001$ between children and adults; * – $p < 0.05$, compared to the first series.

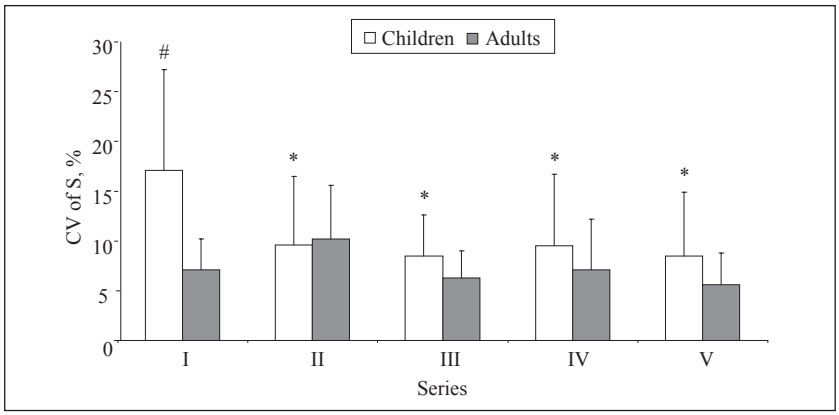


Figure 9. **Changes in CV of path amplitude (S) of children and adults during 5 series of 20 repetitions in the speed-accuracy task**

Note. # – $p < 0.001$ between children and adults; * – $p < 0.05$, compared to the first series.

accuracy task was different between children and adults. Namely**,** the accuracy was most improved by children at the expense of quickness, while adults improved only the average velocity of their performance. It might be assumed that fast motor learning process is more expressed in children than in adults. The underlying mechanism for the fast learning difference between children and adults will still have to be elucidated.

These results of our study are in accord with the data of D. Flamment et al. (1999) which suggest that movement parameters change in adult subjects with different time during the process of motor learning (Flament et al., 1999). However, our results have extended this conclusion, i. e. the time of different performance variables is age-dependent (Fig. 6, 7, 8, 9). It has been suggested more specifically that reaction time in adult subjects was the parameter that changed the fastest and reached a steady baseline earliest while time-related parameters (movement duration) decreased at a somewhat slower rate and plateaued next (Flament et al., 1999). However, there are only Va significant changes during the fast learning period in adult subjects, while RT as well as Vm did not change significantly. This fact is in accord with the data of T. Kempf et al. (2001). They concluded that the movement time was seen to decrease and in a shorter time than peak velocity, which increased and plateaued later.

There were significant changes in the accuracy of the performance in children even after the first series. It might be assumed that children are more prone to develop motor skills during the fast learning period. However, it is not clear why children used the strategy of improving accuracy

at the expense of quickness. It is important to note that in our study the changes in RT and Va correlated significantly in children, as well as in adults. This means that two different variables changed consistently. Besides, we found that changes in S and Vm correlated directly in children. In other words, the more S decreased, the more Vm decreased.

It has been concluded that motor adaptation in timescales of minutes is supported by two distinct processes: one process when a person learns slowly from errors but has strong retention, and another process is when a person learns rapidly from errors but has poor retention (Ethier et al., 2008). We might only assume, that children used the second strategy more that adult, i. e. they learnt rapidly but had poor retention.

The difference between children and adults in the variability of time of the speed-accuracy task. We established that the variability of Va, Vm and S changed significantly after the first series only in children while in adults only the variability of RT gradually decreased. It has been recently concluded that the variability of task performance was more expressed in children than in adults (Kuhtz-Buschbeck et al., 1998; Yan et al., 2000; Jansen-Osmann et al., 2002). This is in accord with the results of our study. We have not come, however, across any publications devoted to the study of differences between children and adults in the variability of time of the speed-accuracy task. Therefore, as far as we know, this is the first study have shown that children were more prone for changes not only in accuracy but in the variability of accuracy, as well as in Va and Vm. It is rather surprising that the variability of RT did not change during the fast learning period in children. It has been proposed that during fast learning motor models are developed in children and adults (Jansen-Osmann et al., 2002). The authors concluded that the neural representations of limb dynamics are less precise in children and less stable in time than those of adults. Therefore, such controller instability might be a primary cause of more variability of performance variables in children compared to adults in our study. It has been, recently, concluded that on-line optimization of movement would depend on the proposed cerebellar mechanisms such as, feed-forward and error correction (Nezafat et al., 2001), development of internal models (Shadmehr, Holcomb, 1997; Wolpert et al., 2001; Cothros et al., 2006; Imamizu et al., 2007).

CONCLUSIONS AND PERSPECTIVES

In conclusion, the time of fast learning in speed-accuracy task was different between children and adults. Namely, the accuracy was most improved by children at the expense of the quickness, while adults improved only the average velocity of their performance. Besides, most of the variability of performance variables changed more significantly in children than in adults. It might be speculated that children are more prone to change motor variables during the fast learning process than adults. Though the underlying mechanism for the fast learning difference between children and adults have to be elucidated, yet it might be speculated that feed-forward and error correction mechanisms as well as the development of internal models are more changeable in children than in adults during the fast learning process.

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VAIKŲ IR SUAUGUSIŲJŲ GREITO IŠMOKIMO TRUKMĖ ATLIEKANT GREITUMO IR TIKSLUMO UŽDUOTIS

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Mokantis judesių įvairiais mokymosi tarpsniais kinta judesių rodikliai.

Tikslas: nustatyti bei palyginti vaikų ir suaugusiųjų greitumo, tikslumo judesių mokymosi ypatybes.

Metodai. Buvo tiriama 13 sveikų berniukų, 16 mergaičių, 5 sveiki vyrai ir 7 moterys. Tyrimas atliktas Lietuvos kūno kultūros akademijos Judesių valdymo laboratorijoje naudojant žmogaus rankų ir kojų dinaminių rodiklių analizatorių (DPA-1). Užduotį tiriamieji atliko dešine ranka. Jie turėjo kuo greičiau reaguoti į kompiuterio ekrane pasirodantį taikinį ir kaip galima greičiau bei tiksliau į jį pataikyti. Buvo registruojamas dešinės rankos maksimalusis ir vidutinis judesio greitis, reakcijos trukmė ir judesio trajektorija.

Rezultatai. Nustatyta reikšmingų skirtumų ($p < 0,05–0,001$) tarp vaikų ir sauaugusiųjų reakcijos trukmės, vidutinio greičio, maksimaliojo greičio ir judesio trajektorijos rodiklių.

Aptarimas ir išvados. Motorinė adaptacija bėgant laikui pasireiškia dviem skirtingais vyksmais: kai asmuo mokosi lėtai iš klaidų ir ilgai atsimena; kai asmuo mokosi iš klaidų greitai, tačiau greitai ir pamiršta (Ethier et al., 2008). Manome, kad vaikai antrą strategiją naudoja dažniau nei suaugusieji. Atliekant greitumo ir tikslumo užduotį vaikų ir suaugusiųjų mokymasis skiriasi. Vaikų tikslumas gerėjo greitumo sąskaita, o suaugusiųjų padidėjo tik vidutinis judesio greitis. Be to, užduotį atliekant vaikams daugumos kintamųjų kaitumas pasikeitė statistiškai reikšmingiau nei tai darant suaugusiesiems.

Raktažodžiai: judesių mokymasis, judesių valdymas, amžius, užduotis rankoms.

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