# HOW DO REACTION TIME AND MOVEMENT SPEED DEPEND ON THE COMPLEXITY OF THE TASK?

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***ABSTRACT***

*The aim of the research was to determine how the reaction time and the movement speed depend on the complexity of the task.*

*The research was carried out in the Laboratory of Human Motor Control at the Lithuanian Academy of Physical Education (LAPE) applying the analyzer of dynamic parameters of human leg and arm movement (DPA-1; Patent No. 5251; 2005 08 25), which is used for the qualitative estimation of the dynamic parameters of one arm and leg target movement, two arms and legs coordinated and independent target movements, when the resistance power and target are coded with different programmable parameters. We registered the reaction time (RT) and the movement speed ($V_{max}$) performing simple tasks of reaction and speed and a complicated task of accuracy.*

*Research results indicated that performing a complicated task the reaction is slower, and the maximal movement speed is lower than performing a simple task. However, it does not mean that movement speed will be higher when the reaction is faster performing a simple task. The data obtained confirmed Hick's law proposing that reaction time is directly proportional to the complexity of the task because performing the tasks of different levels of complexity the reaction time values of the right arm were statistically significantly different ($p < 0.001$).*

*After performing the analysis of variation coefficients we established that the highest coefficient of variation was received from the indices of movement speed performing a speed task (23%), and the lowest — of reaction time performing a reaction task (10%). The obtained results confirm other authors' suggestion that performing a complicated task the reaction time is a more steadily controlled index than maximal movement speed.*

*A strong correlation was determined between the reaction time values performing the tasks of reaction and accuracy, but there was no statistical link between the maximal speed values performing the tasks of speed and accuracy. This indicates that if the movement speed is high performing a simple task, it does not mean that it will be high performing a complicated task.*

*Conclusions: 1) performing a complicated task reaction time is longer, and maximal movement speed is lower than performing a simple task; 2) the complexity of the task more impacts the dispersion of results of the movement speed than of the reaction time; 3) high speed performing a simple task does not indicate that it will be high performing a complicated task.*

***Keywords:*** *reaction time, movement speed, the complexity of the task.*

## INTRODUCTION

The system of human movement (motor system) depends on the complex, dynamic and adaptive systems (Kaplan, Glass, 1995; Kauffman, 1995; Latash, 1998; Kelso, 1999; Wolpert et al., 2001; Goldberger et al., 2002; Skurvydas, Mamkus, 2002; Newell, 2003). The dynamism of movements is an inevitable and essential peculiarity of movement performance, without which movements would lose their stability and adaptivity (Bernstein, 1967; Newell, Corcos, 1993; Kelso, 1999; Davids et al., 2006). Thus, control of dynamic (constantly changing) movements is one of the greatest problems of motor control and motor learning (Scott, 2005).

Recently the scientists have been especially interested in the consisted patterns of motor behavior and the models of motor learning and motor control. There are many studies analyzing reaction time, speed and accuracy of movements as well as their interrelation (Schmidt, Lee, 1999; Fischer et al., 2007). Some researchers refer to Fitts's law which explains the dependence of the duration of rapid and accurate movement on the distance to the target and the size of the target (Plamondon, Alimi, 1997; Schmidt, Lee, 1999; Bootsma et al., 1994; Pratt et al., 2007), others invoke Hick's law which explains the dependence of the reaction time on the complexity of movement (Schmidt, Lee, 1999; Allen et al., 2004). We were unable to find studies analyzing Fitts's and Hick's laws together.

**The aim of the research** was to determine how the reaction time and the movement speed depend on the complexity of the task.

# RESEARCH METHODS

Research participants were 20 healthy males and females involved and not involved in sports. Their age was 26.6 ± 8.07 years, body mass — 70.1 ± 9.38 kg, height — 177 ± 6.81 cm. The subjects were informed about the research procedures.

The research was carried out in the Laboratory of Human Motor Control at the Lithuanian Academy of Physical Education (LAPE) applying the analyzer of dynamic parameters of human leg and arm motion (DPA-1; Patent No. 5251; 2005 08 25), which is used for the qualitative estimation of the dynamic parameters of one arm and leg target movement, two arms and legs coordinated and independent target movements, when the resistance power and target are coded with different programmable geometrical, chromatic and temporarily set parameters.

**Analyzer DPA-1 measuring reaction time, movement speed and accuracy.** The analyzer contains two measuring devices connected to a stationary standard computer with *Windows* (or compatible to it) operating environment, which has an imbedded 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;
- Power supply.

Measuring devices are fastened to the support panel where the handle units slide on its surface. The power supply switch 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 reaction time, movement speed and accuracy.** 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° 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 legs are bent 90° at

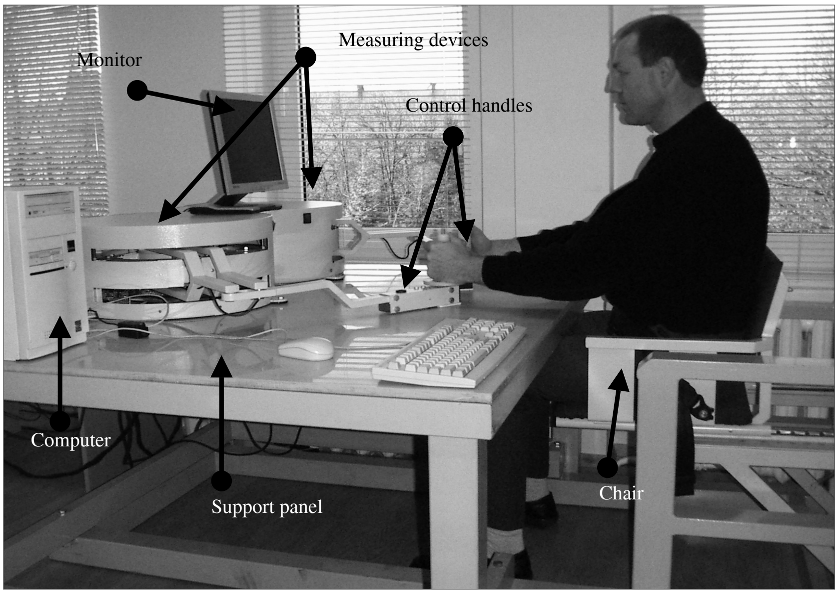



Figure 1. **The analyzer of dynamic parameters of human leg and arm motion (DPA-1)**

the knees and the feet rest on the floor. 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 70 cm.

The subjects perform the tests with their right arm. In accordance with the tasks of the test prepared in advance, a target — a red circle 7 mm in diameter — appears on the screen at stated intervals. During each task the subject sets the handle symbol of 3.5 mm in diameter to the start zone (the center of a green circle the diameter of which is 10 mm) 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 drag force of which equals to 20 N. The distance between the centers of the start circle and the target circle is 170 mm. The measurement cycle is completed after performing a movement or hitting the target (depending on the task). The information about the task performed is stored in the computer memory and later it is transferred to *Microsoft Excel* program.

**Research procedures of the reaction time, movement speed and accuracy.** The subjects performed three tasks: reaction, speed and accuracy. The reaction task was as follows: the subjects had to react as quickly as possible and to move the handle of the device. After explaining the task they were allowed to take three tries, the results of which were not recorded. Then the task was performed 20 times successively registering the reaction time (RT) of the right arm in ms.

After 5 minutes the subjects performed the speed task — as soon as they heard the sound signal, they had to stretch their right arm, holding the handle of the device, at the elbow joint as fast as they could. Three tries were allowed, and their results were not recorded. Then the task was repeated five times in success. We registered the maximal movement speed ($W_{max}$; mm / s) of the right arm.

The accuracy task was performed five minutes after the speed task. The subjects 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. 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 20 times in success. We registered the reaction time (RT-T) of the right hand (ms) and the maximal movement speed ($V_{max}$-T) (mm / s).

After each repetition the subjects could see their achieved result on the computer screen, besides they were motivated verbally to do their best.

**Methods of mathematical statistics.** We calculated the values of arithmetic mean ($\overline{x}$), root mean square deviation ($\sigma$), coefficient of variation ($V_A$ %) and the Pearson correlation coefficient ($r$) of the indicators produced by the subjects. Reliability of the sample differences was estimated applying Student's $t$ test.

## RESEARCH RESULTS

We established statistically significant differences ($p < 0.001$) between the mean values of reaction time performing the tasks of reaction and accuracy, 237.8 ± 22.9 ms and 321.1 ± 52.0 ms respectively (Fig. 2).

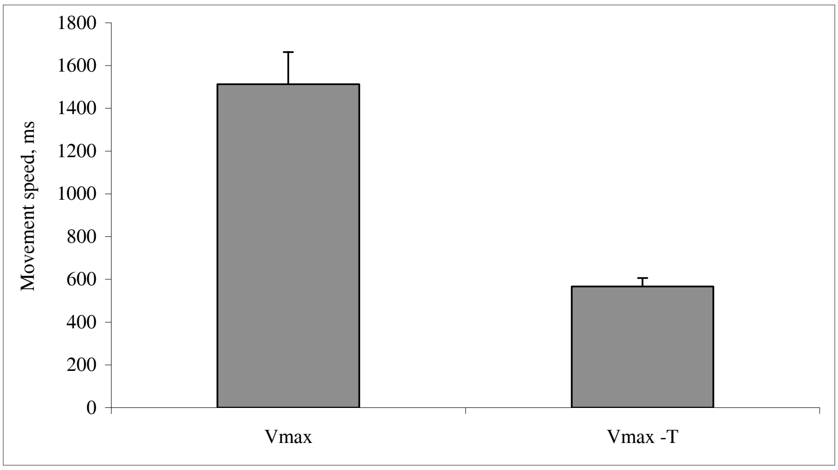
The maximal movement speed of the right arm was statistically significantly ($p < 0.001$) higher performing the speed task (1513.3 ± 342.8 mm / s) compared to the task of accuracy (566.9 ± 91.1 mm / s) (Fig. 3).

Aiming to estimate the dispersion of the indices in our study we calculated the coefficients of variation of different tasks. The least coefficient of variation was that of the reaction time performing a simple reaction task (10%). The greatest coefficient of variation was the coefficient of maximal movement speed performing a simple speed task (23%) (Table 1).

Table 2 includes the correlated links between the reaction time and the maximal speed performing the tasks of reaction, speed and accuracy.

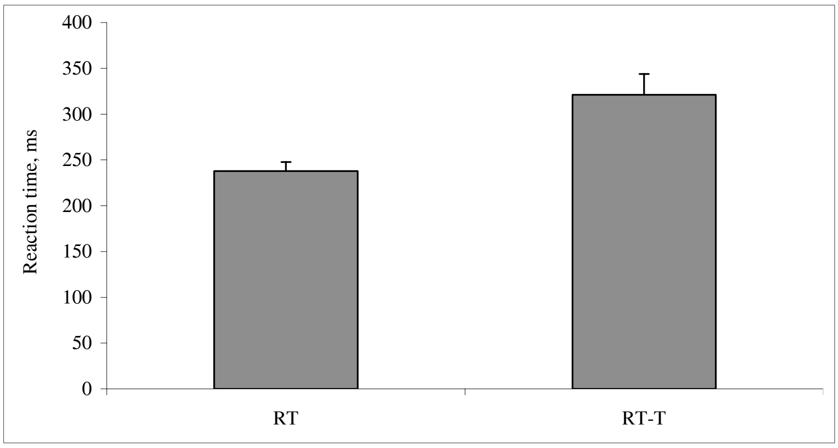
The analysis of correlated links revealed a strong reciprocal statistical relation between the indices of reaction time and maximal speed movement (–0.71) performing the task of "accuracy". We suggest that performing a complicated task the higher movement speed is produced by those subjects who faster respond to the stimulus. It is worth noting that performing a simple task the statistical link between those two indices was rather weak (–0.23). The correlation between reaction times performing reaction and accuracy tasks was 0.56, but no statistical link was found between the maximal speed values performing the speed and accuracy tasks (–0.09).

Figure 2. **The mean values of reaction time (ms) performing the tasks of reaction (RT) and accuracy (RT-T)**




**Note.** * — $p < 0.05$, comparing RT and RT-T results.

Figure 3. **The mean values of maximal movement speed (cm/s) performing the tests of speed ($V_{max}$) and accuracy ($V_{max}$ – T)**




**Note.** * — $p < 0.05$, comparing $V_{max}$ and $V_{max}$ – T results.

Table 1. **Variation coefficients of reaction time and maximal movement speed performing the tasks of reaction, speed and accuracy**

| **Parameters** | **RT, %** | **$V_{max}$, %** |
|---|---|---|
| Reaction task | 9.6 | — |
| Speed task | — | 22.7 |
| Accuracy task | 16.2 | 16.0 |

Table 2. **Correlation coefficients between the results of reaction, speed and accuracy tasks**

| **Parameters** | **RT** | **RT-T** | **$V_{max}$** | **$V_{max}$-T** |
|---|---|---|---|---|
| RT | 1 | | | |
| RT-T | 0.56 | 1 | | |
| Vmax | – 0.26 | – 0.07 | 1 | |
| Vmax-T | – 0.23 | – 0.71 | – 0.09 | 1 |

# DISCUSSION

Answering the question how reaction time and movement speed depend on the complexity of the task we suggest that performing a complicated task the reaction is slower, and the maximal movement speed is lower than performing a simple task. However, it does not mean that the movement speed will be higher if the reaction is faster performing a simple task.

The obtained results confirm other researches proposition that the more complicated movement is needed to be planned, the longer is the time of planning that movement, which is indicated by the reaction time from the beginning of a stimulus till the beginning of the movement (Schmidt, Lee, 1999; Muckus, 2003). Research results indicated that performing the tasks of different levels of complexity the reaction time values of the right arm were statistically significantly different ($p < 0.001$). This fact has confirmed Hick's law that reaction time is directly proportional to the complexity of the task (Jensen, 1998; Gignac, Vernon, 2004). However, research findings obtained by other authors have shown that the indices of the reaction time performing the tasks of different levels of complexity do not differ statistically significantly (Shen Yin-Chen, Franz, 2005). The authors claim that the impact of the tasks of different types on the reaction time was subdued by the specifications of the task which were usual and known in advance (Zuozienė et al., 2005).

Researchers suggest that it is rather difficult to combine movement speed and accuracy because when the movement is performed faster, its duration decreases together with the possibilities of its correction (Schmidt, Lee, 1999). Analyzing the indices of maximal movement speed in the tasks of speed and accuracy we found that maximal speed value in the task of speed was 62.5% greater than performing a complicated accuracy task. Similar differences in dynamic and kinematic results were determined by other authors (Brouwer et al., 2001; Lewis et al., 2002) as well.

The complexity of the task makes a greater impact on the dispersion of movement speed results compared to the reaction time results. Dispersion of variants is considered to be low if the coefficient of variation amounts from 0 to 10%, average — form 10 to 20%, and high — more than 20% (Gonestas, Strielčiūnas, 2003). The highest coefficient of variation was received from the indices of movement speed performing a simple task (23%), and the lowest — of reaction time performing a simple task (10%). The obtained results confirm other authors' suggestion that performing a complicated task the reaction time is a more steadily controlled index than maximal movement speed (Zuozienė et al., 2005). However, this can be due to the fact that performing the speed task the repetitions were fewer compared to the tasks of reaction and accuracy.

A strong correlation was determined between the reaction time values performing the tasks of reaction and accuracy, but there was no statistical link between the maximal speed values performing the tasks of speed and accuracy. This indicates that if the movement speed is high performing a simple task, it does not mean that it will be high performing a complicated task. We suppose that this is determined by different physiological and psychological mechanisms. Reaction time is more associated with planning the task, and movement speed more depends on the speed of muscle contraction.

## CONCLUSIONS

1. Performing a complicated task reaction time is longer, and maximal movement speed is lower than performing a simple task.
2. The complexity of the task more impacts the dispersion of results of the movement speed than of the reaction time.
3. High speed performing a simple task does not indicate that it will be high performing a complicated task.

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# KAIP REAKCIJOS LAIKAS IR JUDESIŲ GREITIS PRIKLAUSO NUO UŽDUOTIES SUDĖTINGUMO?

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## SANTRAUKA

Tyrimo tikslas — nustatyti, kaip reakcijos laikas ir judesio greitis priklauso nuo užduoties sudėtingumo.

Tyrimai atlikti Lietuvos kūno kultūros akademijos (LKKA) Judesių valdymo laboratorijoje naudojant žmogaus rankų ir kojų judesių dinaminių parametrų analizatorių (DPA-1) (patento Nr. 5251; 2005 08 25), skirtą kokybiniams vienos rankos, kojos tikslinio judesio, dviejų rankų, kojų koordinuotų ar nepriklausomų tikslinių judesių dinaminiams parametrams išmatuoti. Buvo registruojamas 20 sveikų vyrų ir moterų dešinės rankos reakcijos laikas (RT) ir judesio greitis ($V_{max}$) atliekant reakcijos, greitumo ir tikslumo užduotis.

Rezultatų analizė parodė, kad atliekant sudėtingą užduotį reaguojama lėčiau, o maksimalus judesio greitis yra mažesnis nei atliekant paprastą užduotį. Judesio greitis bus didesnis tuomet, kai bus greičiau reaguojama atliekant paprastą užduotį. Gauti duomenys patvirtina Hicko dėsnį, kuris teigia, kad reakcijos laikas yra tiesiog proporcingas užduoties sudėtingumui — atliekant skirtingo sudėtingumo užduotis dešinės rankos judesio reakcijos laikas statistiškai patikimai skyrėsi ($p < 0{,}001$).

Atlikus variacijos koeficientų analizę nustatyta, kad didžiausias variacijos koeficientas yra maksimalaus judesio greičio rodiklių, atliekant greitumo užduotį (23%), mažiausias — reakcijos laiko, atliekant reakcijos užduotį (10%). Gauti rezultatai patvirtina kitų autorių teiginį, kad atliekant sudėtingą užduotį reagavimo laikas yra patikimiau valdomas rodiklis nei maksimalusis judesio greitis.

Nustatytas stiprus koreliacinis ryšys tarp reakcijos laiko atliekant reakcijos ir tikslumo užduotis, tačiau tarp maksimalaus judesio greičio, atliekant greitumo ir tikslumo užduotis, statistinio ryšio neaptikta. Vadinasi, didelis judesio greitis atliekant paprastą užduotį dar nerodo, kad jis toks bus atliekant ir sudėtingą užduotį.

Išvados: 1) atliekant sudėtingą užduotį reakcijos laikas yra ilgesnis, o maksimalus greitis mažesnis nei atliekant paprastą užduotį; 2) kuo sudėtingesnė užduotis, tuo jos atlikimo greitis didesnis, o reakcijos laikas nekinta; 3) didelis greitis atliekant paprastą užduotį nerodo, kad jis toks bus ir atliekant sudėtingą užduotį.

**Raktažodžiai:** reakcijos laikas, judesių greitis, užduoties sudėtingumas.

Gauta 2008 m. kovo 7 d.
Received on March 7, 2008

Priimta 2008 m. birželio 18 d.
Accepted on June 18, 2008

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