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INVOLUTION OF SIMPLE AND COMPLEX REACTION TIMES AMONG PEOPLE AGED BETWEEN 21 AND 80 – THE RESULTS OF COMPUTER TESTS

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ABSTRACT
Purpose. The aim of this case study is to define the involution of simple and complex reaction times in groups of adult men and women. **Basic procedure.** The tests were carried out during the years 2007–2008 among 128 men and 136 women aged between 21 and 80. Those examined were divided into three groups according to their calendar age. In order to define the meaning of differences of the analyzed reaction time between the results of the three age groups, the analysis of variance (ANOVA) method for independent attempts was used. Additionally, normalized differences between the groups as well as indices of sexual dimorphism were defined. **Main findings.** Among both men and women, gradual deterioration of reaction time performance with age can be observed. The scale of normalized differences shows that the most distinct differences are noticed between the first and the third group. They amount up to 1.3 of the standard deviation in men and up to 1.7 in women. **Conclusions.** The results derived from the following study confirm a long period of relative stabilization for all simple and complex reaction times among both genders. Significant involution of reaction times can be observed for all analyzed features only after the age of 55. Indices of sexual dimorphism indicate that men gain better results in all age groups. Indices of sexual dimorphism diminish with age.

Key words: coordination motor abilities, reaction time, involution, sexual dimorphism

Introduction

Nowadays, there are over 650 million people at the age of 60 or older around the world. According to a demographic forecast made by WHO [1], this number will increase to about 1.2 billion in the year 2025 and about 2 billion in 2050. The forecast made by the Central Statistical Office also indicates that Polish society is ageing. It is estimated that in 2030–2035 every fourth Pole will be an old-age-pensioner. The extension of average life expectancy causes new challenges for social, health and preventive politics. It is necessary to emphasise that only systematic physical exercise will allow a person to be healthy, keep fit and enjoy oneself until the end of their life. Readers can make themselves acquainted with an extensive overview of literature on the influence and importance of physical exercise among elderly people in survey works by Osiński [2] and Drabik [3]. Many authors [4–8] stress that the 'style of life' in earlier periods of ontogenesis undoubtedly influences the level of motor abilities. It is vital to promote adequate programmes in order to raise the quality of one's lifestyle [9, 10].

It appears from the overview of literature that there are a lot of studies on the course of progressive development. Issues related to physical as well as functional development seem to be discussed very deeply. However, there are decidedly fewer research papers on involuntary changes in mature years and in the period of ageing. Most research works on the subject are mainly concerned with changes of basic somatic parameters (height, body mass and its components). There are definitely considerably fewer reliable research works based on a vast number of people that evaluate changes comprehensively, both on the level of functional and somatic parameters [11–15].

Conditions of human existence in the contemporary world cause higher and higher requirements for a person. With the progress of civilization, preferences in motor abilities are changing. Nowadays, in times of common automation and computerization, most authors emphasize the importance and meaning of coordination motor abilities. The level of their development, involution with age, determinants, dimorphic diversity, as well as fitness training among elderly people are extensively described in a survey work by Lyakh [16]. This author intensively analyses about 100 titles from Polish and foreign literature on the subject of coordination among elderly people. Similar issues are also dis-

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cussed by Starosta in his work [17]. As far as elderly people and children are concerned, most studies on coordination abilities are connected with reaction times (overview of research papers [13, 18]). However, the analysis of literature shows that due to the specified period of research, equipment and the amount of material, the results were sometimes divergent. In this situation a new approach to the subject seems to be justified.

The aim of the following case study is to define the regress of simple and complex reaction times in a group of adult men and women aged between 21 and 80. The research and its results will provide answers to the following questions:

1. What are the size, range and direction of diversity among the examined factions determined on the basis of normalized differences between the groups?
2. Which abilities show the largest sexual diversity?
3. How do indices of sexual dimorphism shape the chosen calendar age groups?

Material and methods

The material of the case study comprises the results of simple and complex reaction times to visual and acoustic stimuli. The tests were carried out during the years 2007–2008 among 264 men and women aged between 21 and 80. The examined individuals people were divided into three groups according to their age (up to 35; between 36 and 55; and above the age of 56).

The number of characters in three separate age factions is presented in Table 1.

Table 1. Number of tested people in three calendar age group

Group	Male		Female	
	N	$\bar{x}$ age	*N*	$\bar{x}$ age
Group I (21–35 calendar age)	29	32.00	63	31.53
Group II (36–55 calendar age)	51	42.80	33	43.42
Group III (56–80 calendar age)	48	67.75	40	68.30
TOTAL	128		136	

Some selected types of reaction time were considered: reaction time to the visual stimulus (minimal, average, maximal), reaction time to the acoustic stimulus (minimal, average, maximal) and complex reaction time (minimal, average, maximal). The tests were positively verified as far as reliability and accuracy are concerned [19, 20]. The precise description of each test together with the measurement units is included in the aforementioned work. The tests (performed in a quiet and calm room) were made with the use of a mobile computer "tablet" with touch screen (Toshiba Satellite R15).

Statistical methods for handling the material:

1. Basic statistical characteristics of the examined coordination motor abilities were calculated in three factions divided according to age and gender. Normality of arrangements was verified by means of the Shapiro-Wilk W test. Homogeneity of variance was evaluated by means of the Levene's test [21].
2. In order to define the meaning of differences of the analyzed reaction time between the results of the 3 age groups, the analysis of variance (ANOVA) method for independent attempts was used. The Tukey's Post Hoc Test for various *N* was used.
3. The size, range and direction of diversity of tested reaction times between the 3 age groups were determined on the basis of normalized intergroup differences. The normalization was used for the oldest group mean and standard deviation.
4. In order to examine the range of diversification between male and female subjects, standardized indices of sexual dimorphism were calculated (ISD), according to the equation developed by Szopa et al. [22]:

$$ISD = \frac{2(\bar{x}_m - \bar{x}_w)}{SD_m + SD_w},$$

where:
$\bar{x}_m$ – arithmetic mean of the men in their calendar age group
$\bar{x}_w$ – arithmetic mean of the women in their calendar age group
SD_m – standard deviation of the men in their calendar age group
SD_w – standard deviation of the women in their calendar age group.

The research results were analyzed with the use of STATISTICA PL v. 6.0 software.

Results

Basic statistical characteristics of the analyzed reaction times among men in the three chosen calendar age groups are presented in Table 2. The analysis of arithmetic averages shows gradual deterioration of performance with age. This regularity concerns all analyzed features. Table 2 also includes the evaluation of statistical significance of arithmetic average differences concerning the examined reaction times between the per-

Table 2. Basic statistical parameters of the analysed men's features in calendar age classes as well as statistical significance of differences between groups (in milliseconds)

Variable	Group I 21–35 calendar age		Group II 36–55 calendar age		Group III 56–80 calendar age	
	$\bar{x}$ ± SD	*p* I–II	$\bar{x}$ ± SD	*p* II–III	$\bar{x}$ ± SD	*p* I–III
Reaction time to the visual stimulus – minimal	235.51 ± 19.00	0.836	249.80 ± 34.78	**0.000**	396.72 ± 150.82	**0.000**
Reaction time to the visual stimulus – average	259.62 ± 27.87	0.693	283.80 ± 46.00	**0.000**	477.06 ± 177.76	**0.000**
Reaction time to the visual stimulus – maximal	298.27 ± 54.12	0.543	339.21 ± 82.17	**0.000**	583.12 ± 220.07	**0.000**
Reaction time to the acoustic stimulus – minimal	197.93 ± 22.57	0.568	230.98 ± 74.41	**0.000**	408.12 ± 186.54	**0.000**
Reaction time to the acoustic stimulus – average	216.13 ± 22.15	0.433	262.02 ± 87.99	**0.000**	485.75 ± 211.46	**0.000**
Reaction time to the acoustic stimulus – maximal	244.82 ± 27.85	0.328	310.58 ± 131.58	**0.000**	581.62 ± 251.68	**0.000**
Complex reaction time – minimal	283.44 ± 43.93	0.644	312.74 ± 79.22	**0.000**	509.85 ± 183.51	**0.000**
Complex reaction time – average	420.00 ± 69.07	0.497	466.84 ± 100.56	**0.000**	732.83 ± 230.18	**0.000**
Complex reaction time – maximal	612.07 ± 142.18	0.630	668.43 ± 142.56	**0.000**	1045.31 ± 339.30	**0.000**

Quantities in bold mean significant differences between averages at least on the level of $p \leq 0.05$

Table 3. Basic statistical parameters of the analysed women's features in calendar age classes as well as statistical significance of differences between groups (in milliseconds)

Variable	Group I 21–35 calendar age		Group II 36–55 calendar age		Group III 56–80 calendar age	
	$\bar{x}$ ± SD	*p* I–II	$\bar{x}$ ± SD	*p* II–III	$\bar{x}$ ± SD	*p* I–III
Reaction time to the visual stimulus – minimal	255.35 ± 34.05	0.321	281.00 ± 68.64	**0.000**	431.36 ± 122.83	**0.000**
Reaction time to the visual stimulus – average	282.17 ± 40.44	0.113	322.50 ± 80.18	**0.000**	520.75 ± 136.64	**0.000**
Reaction time to the visual stimulus – maximal	317.14 ± 53.28	0.161	365.37 ± 101.48	**0.000**	605.48 ± 189.74	**0.000**
Reaction time to the acoustic stimulus – minimal	210.35 ± 27.56	0.388	235.15 ± 46.17	**0.000**	409.51 ± 145.10	**0.000**
Reaction time to the acoustic stimulus – average	231.60 ± 30.05	0.231	270.62 ± 60.47	**0.000**	515.51 ± 183.29	**0.000**
Reaction time to the acoustic stimulus – maximal	260.35 ± 43.77	0.075	376.25 ± 97.52	**0.000**	689.12 ± 245.30	**0.000**
Complex reaction time – minimal	300.17 ± 60.88	0.228	337.12 ± 81.01	**0.000**	486.58 ± 149.24	**0.000**
Complex reaction time – average	451.91 ± 77.28	0.345	481.32 ± 78.98	**0.000**	723.07 ± 166.11	**0.000**
Complex reaction time – maximal	662.68 ± 184.92	0.155	743.25 ± 177.60	**0.000**	1046.60 ± 274.44	**0.000**

Quantities in bold mean significant differences between averages at least on the level of $p \leq 0.05$

Table 4. The sizes of normalized intergroup differences of the tested reaction times between chosen calendar age groups

Variable	Male				Female			
	d_1	z_1	d_2	z_2	d_1	z_1	d_2	z_2
Reaction time to the visual stimulus – minimal	–161.21	–1.07	–146.92	–0.97	–176.01	–1.43	–150.36	–1,22
Reaction time to the visual stimulus – average	–217.44	–1.22	–196.26	–1.08	–238.58	–1.75	–198.25	–1.45
Reaction time to the visual stimulus – maximal	–284.85	–1.29	–243.91	–1.10	–288.34	–1.52	–240.11	–1.26
Reaction time to the acoustic stimulus – minimal	–210.19	–1.13	–177.14	–0.95	–199.16	–1.37	–174.36	–1.20
Reaction time to the acoustic stimulus – average	–269.62	–1.27	–223.73	–1.06	–283.91	–1.55	–244.89	–1.34
Reaction time to the acoustic stimulus – maximal	–336.80	–1.33	–271.04	–1.07	–428.77	–1.75	–312.87	–1.27
Complex reaction time – minimal	–226.41	–1.23	–197.11	–1.07	–186.41	–1.25	–149.46	–1.00
Complex reaction time – average	–303.83	–1.32	–265.99	–1.15	–271.16	–1.63	–241.75	–1.45
Complex reaction time – maximal	–433.24	–1.27	–376.88	–1.11	–383.92	–1.40	–303.35	–1.11

$d_1 = \bar{x}_{GrI} - \bar{x}_{GRIII}$; $z_1 = d_1/SD_{GRIII}$; $d_2 = \bar{x}_{GRII} - \bar{x}_{GRIII}$; $z_2 = d_2/SD_{GRIII}$

Table 5. Variation with age indices of sexual dimorphism (ISD) of individual reaction times in chosen age groups

Variable	ISD values		
	Group I 21–35 calendar age	Group II 36–55 calendar age	Group III 56–80 calendar age
Reaction time to the visual stimulus – minimal	–0.75	–0.60	–0.25
Reaction time to the visual stimulus – average	–0.66	–0.61	–0.27
Reaction time to the visual stimulus – maximal	–0.35	–0.28	–0.11
Reaction time to the acoustic stimulus – minimal	–0.49	–0.07	–0.01
Reaction time to the acoustic stimulus – average	–0.59	–0.12	–0.14
Reaction time to the acoustic stimulus – maximal	–0.41	–0.57	–0.43
Complex reaction time – minimal	–0.32	–0.30	–0.14
Complex reaction time – average	–0.44	–0.16	0.05
Complex reaction time – maximal	–0.50	–0.46	–0.01

formances of men from three calendar age groups. The conducted analysis presents unequivocally that no significant deterioration of the results concerning all features between groups I and II can be noticed. By contrast, in all cases the results of variance analysis show significant statistical differences in average reaction times among groups II and III as well as between the outermost groups.

In turn, Table 3 presents basic statistical characteristics as well as the results of variance analysis ANOVA for the analyzed features among women. The obtained results reveal similar regularities to those obtained by men. Again gradual deterioration of arithmetic averages with age as well as statistically significant differences between groups II and III, and between groups I and III (in all cases), are observed.

Regardless of the significance of differences evaluation, it is worth observing how their direction and size shape. To do that the results of all analyzed features were normalized in order to obtain the average as well as the standard deviation for the oldest group. The results for men are presented in Table 4. Our analysis will start with the size of normalized differences between the outermost groups (z_1). On the whole, it can be stated that the direction of diversity for all features is in accordance with the assumed age gradient ('minus' illustrates worse results in the older group). The scale of diversity is quite significant because it amounts to about 1.3 of standard deviation for almost all features. Then, analysing normalized differences of the results between groups II and III again, better results are noticed among men from the younger group. However, the scale of diversity is slightly smaller and it fluctuates within 1 of standard deviation.

Normalized differences obtained by women are also presented in Table 4. Similarly to men, the most significant normalized differences are observed between the outermost groups (I–III). The sizes of z_1 show definitely better results for all examined features among the youngest women. The scale of diversity is slightly bigger than the one observed among men. The sizes of z_1 are contained within –1.25 to –1.75 of standard deviation. In turn, normalized differences z_2 are slightly smaller but still show definitely better reaction times in the group of younger women. The sizes of z_2 fluctuate within 1.3 of standard deviation.

Additionally, the subject of the analysis was variability with age of normalized indices of sexual dimorphism (ISD) of the examined reaction times. The results presented in Table 5 indicate unequivocally that in the discussed period and for all the test differences between genders shape in favour of men. Among all analyzed features, the highest indices of sexual dimorphism were observed for velocity of reaction to visual stimulus – minimal (I group, ISD = –0.75). However, analysing variability ISD values in age groups, it can be stated that the scale of differences between genders diminishes with age of the individuals examined. Thus, indices of ISD in the first age group are comprised within –0.75 and –0.32, in the second group within –0.61 and –0.12, and in the third group within 0.43 and 0.05.

Discussion

It has already been mentioned in the introduction that comparing the obtained results with the data included in literature is considerably limited. Different types of test equipment with various strength of stimuli emission (usually not given), computer tests (computers with different parameters and programs) as well as population tests ('grab at Ditrich stick', stopping a falling target, etc.) have been applied while examining reaction times. These limits lead to various research results, which can therefore be treated only approximately.

It can be stated from the overview of literature [13, 18, 23–25] that the progressive period of developing velocity of reaction lasts up to the age of 16–17 among women and up to the age of 19 among men. By contrast, Mleczko [26, 27] as well as Raczek and Mynarski [28] found that this period ends at about the age of 11–13 among girls and about 13–14 among boys. However, the velocity of complex reaction times reaches its highest level much later that is at about the age of 17–20. After the period of developing, long stabilization starts that is relatively moderate involution. On the basis of Szopa's research [13], it can be deduced that among men between the age of 17–19 and 55 reaction time to visual stimulus deteriorates only by 8.3% while among women by 18.9%. Reaction time to acoustic stimulus seems to have bigger dynamics of involution (11.3% among men, 24.5% among women). Moreover, a very long period of stabilization for reaction times to visual stimulus was obtained among a rural population settled around Żywiec [29]. German research findings show slow involution of most coordination abilities from the age of 30–35 to the age of 45–50 [30, 31]. Only after the age of 65 was a significant tendency of reduction in the level of coordination abilities observed in these studies. Slightly different results in a group aged 7 to 70 were obtained by Hirtz [32]. The level of compound reaction time among participants aged 55 was slightly higher than in the group of participants aged 20. However, such findings are very rare.

By contrast, the analysis of arithmetic averages of reaction times in the whole period of ontogenesis shows definitely better results (among both sexes) in the velocity of visual rather than acoustic reaction. The only exception is the data obtained by Mleczko [18] and Szopa [13]. The authors explain such an arrangement of arithmetic averages as a result of applying relatively weak stimulus in measuring the velocity of acoustic reaction.

The results derived from this study confirm a long period of relative stabilization for all compound and complex reaction times among both sexes. By the age of about 55, the results of variance analysis show that differences of arithmetic averages (between Groups I and II) are statistically insignificant. Involution that can be observed becomes more intensive only after the age of 56–65, which is proved by data concerning normalized results between outermost calendar age groups. All studies quoted above were only connected with average reaction times, as there are no findings on the subject of involution of maximum and minimal times in literature. The results of the present research confirm regularities observed for average reaction times. In this research, a higher level of arithmetic averages of acoustic rather than visual reaction is recognised in all age groups and among both sexes. It is in accordance with the data found in almost every comparative material.

Additionally, the objective of the study was to evaluate dimorphic differentiation of analyzed features in chosen calendar age groups. From the overview of literature quoted above, it was determined that men achieve better results than women during nearly the entire whole period of ontogenesis. The analysis of the obtained results makes it possible to formulate similar conclusions. Moreover, the regularity observed in studies by Szopa et al. [22] concerning a smaller scale of dimorphic diversity of acoustic rather than visual reaction times was confirmed as well. However, the results of the study show unambiguously that indices of sexual dimorphism diminish with the age of the participants. These results cannot be proved by the data on Cracow's population [13]. However, they are in accordance with common observations concerning ontogenesis variability of coordination abilities [33].

On the whole, it can be stated that in most cases boys and men get better results as far as psychomotor abilities are concerned with an occasional advantage in favour of pubescent age women [11]. Such an effect is likely generated by characteristics of male and female nervous systems, strength of genetic and environmental conditions of functional features, as well as the psychoneurological sphere.

Conclusions

As far as the examined population is concerned, influence of calendar age on the reaction times among both sexes is noticed. It means a gradual deterioration of performances with the age of the examined individuals. This phenomenon is especially distinct after the age of about 55.

Sexual dimorphism indices prove that men present a higher level of the analyzed reaction times. Among all analyzed features the highest sexual dimorphism indices were observed for visual minimal reaction time.

Sexual dimorphism indices diminish with the age of those examined.

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