EXPERIMENTAL STUDY

Human information processing in different age

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Abstract

The aim of investigation was to study the aging pecularities of information processing organization. 60 men and 90 women in four age groups: 30–39, 40–49, 50–59 and 60–65 were examined. The information processing was modeled by special computer test with working algorithm changes. The time and accuracy of each assignment were registered for each person. The psychophysiological mechanisms of informational processing were studied by informative mathematical methods. The results are showed that within the aging reduction of perception, processing and speed of reaction in older. As a result of the negative influence of aging shows the decline of mental activity efficiency. Aging decrease on mental capability provokes the compensation of psychophysiological mechanisms of adaptation. The main mechanism increases the psychophysiological organization stochastic and changes the type organization in informational processing to a self-finishing quest response. ***(Tab. 5, Ref. 22.)***
Key words: aging, information processing, psychophysiological mechanisms.

Modern gerontology research shows a decline in the sensory-motor reaction, deterioration of information processing and reduction of mental capability with aging (Katzman, 1976; Arlinger, 1989; Carella, 1990; Monk, 1990; Arbuckle et al, 1994). However, the age-related decline of information processing leads to an increased fatigue and deterioration of the cognitive functions, especially memory and thinking (Gallagher et al, 1994; Falkenstein et al, 2000).

The following physiological adaptation reactions arise which prevent the destabilization of aging process. The adaptation theory of aging is based on this thesis (Frolkis, 1993).

The aging changes of psychophysiological functions are very serious and multifactorial. The use of traditional statistical methods analyze these changes was insufficient. The application the informative mathematical methods to study of information processing are topical. Unfortunately, studies on the informational processing in different age are lacking.

Thus, our goal was to study the human information processing in different age.

Methods

Human subjects (100 males and 110 females) belonging to the four age groups (30–39, 40–49, 50–60 and 60–65 years) were examined. The visual perception and information processing were studied by a special computer test with three algorithm changes.

First algorithm

Four digits (from 0 to 9) are presented on the computer's monitor randomly. The subjects were requested to perform a combination digit test, the task was to calculate (in mind) the number of digits transposed on the display in the increasing order.

For example:

5 2 3 4 – initial order
2 5 3 4 – first transposition
2 3 5 4 – second transposition
2 3 4 5 – final transposition, the result.

Thus, the result of this task consists of "3" transpositions which need four digits on the display in the increasing order. To answer, a person must press the computer's key "3".

Second algorithm

Four digits (from 0 to 9) are presented on the computer's monitor randomly. The subjects were requested to perform a combination digit test, the task was to calculate (in mind) the number of digits transposed on the display in the decreasing order.

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For example:
0 4 7 8 – initial order
0 4 8 7 – first transposition
0 8 4 7 – second transposition
8 0 4 7 – third transposition
8 0 7 4 – fourth transposition
8 7 0 4 – fifth transposition
8 7 4 0 – final transposition, the result.

Thus, the result of this task consists of "6" transpositions which need four digits on the display in order to calculate (in mind) the number of digits transposed on the display in the decreasing order. To answer, a person must press the computer's key "6".

Third algorithm

Seven digits (from 0 to 7) are presented on the computer's monitor randomly. In each figure, one digit is absent. The subjects were requested to find a missing digit among the following seven digits.

For example:
0 4 7 6 5 1 2

The result of this task consists of digit "3", which is missing in this row. To answer, a person must press the computer's key "3".

The time and the accuracy of performing each assignment were registered for each person. The duration of a whole informational process was 9 minutes (3 minutes for each test). The used model of visual perception and informational processing was submitted as part of the computer's system of psychophysiological capacity diagnosis (Polyakov et al, 1995).

Based on the testing results, the following psychophysiological parameters were determined: attention volume (AV) and operational thinking coefficient (OT):

$$AV = (Nr/N)^{*}\, 100\ \% \qquad (1)$$

where
Nr – the number of tasks performed successfully,
N – the number of all tasks performed.

$$OT = (Nr/T)^{*}\, 100 \qquad (2)$$

where
T – time of solving a test problem (msec),
100 – coefficient.

For the evaluation of time perception, we used a modified "individual minute" test proposed by Halberg, 1978 (time perception error, TPE).

The memory function was determined by using a method for measuring short-term memory volume (MV), which consists in estimating the correctly memorized digits among twelve two-digit figures presented for a subject on a display within 30 s.

The use of traditional statistical methods analysis for study of the visual perception and informational processing capability in aging was insufficient. The application of informative mathematical methods to the study of these processes was more correct. The information processing was studied by informative mathematical methods. According to entropy of systems by Shannon (1948) Glushkov (1963) and Antomonov (1969) are proposed the self-organization theory. One of the major parameters of the system organization (as a reflection of the information processing) is the following organization measure:

$$R = 1 - \frac{H}{Hm} \qquad (3)$$

where
R – measure of system organization (by Glushkov, 1963),
H – current entropy,
Hm – maximum entropy.

The current entropy was determined by Shannon:

$$H = -\sum_{i=1}^{n} Pi*logPi \qquad (4)$$

where
Pi – probability of i-state system,
n – number of system states.

Probability of i-state system in informational processing was determined:

$$Pi = \frac{Nr}{N} \qquad (5)$$

where
Nc – number of correct information processing,
N – number of total information processing.

Maximum entropy was determined:

$$Hm = \log n \qquad (6)$$

The number of system states for visual information processing was determined as maximum number of one information processing stimulus (according to first and second algorithm n=6N, for third algorithm n=N).

Results

The results of the study are presented in Table 1. It is seen from the table that average data on the attention volume (AV), short-term memory volume (MV), and operational thinking (OT) are higher in men than in women. The time perception error (TPE) is greater in women vs. men. These data indicate the best cognitive functioning in terms of perception, attention, memory and thinking in men compared to women. The values for aging dif-

Tab. 1. Psychophysiological parameters in different age and sex groups.

Age	groups	TPE, %	AV, %	MV, %	OT
30–39	Men	7.70±2.51	84.51±6.01	55.91±3.51	14.50±4.47
	Women	7.89±1.46	79.30±4.41	53.50±3.54	8.63±0.97*
40–49	Men	7.62±1.33	88.22±4.55	46.77±4.81x	9.62±1.66x
	Women	12.55±1.73*x	82.11±5.28	56.25±3.46*	7.77±0.96*
50–60	Men	8.72±2.44	55.82±7.13x	39.91±7.23	4.75±0.96x
	Women	13.72±1.77*	64.43±5.69x	43.83±4.25x	6.08±0.86*
60–65	Men	9.33±2.52	62.45±4.91x	48.51±5.53	2.25±0.36x
	Women	10.81±1.33*	50.14±4.96x	39.23±2.12x	2.66±0.58*

* – p<0.05 compared to the men;
x – p<0.05 compared to the previous age group.

Tab. 2. The organization of information processing in men of different age groups.

Age groups	First algorithm	Second algorithm	Third algorithm
30–39	0.75±0.08	0.84±0.07*	0.98±0.01*
40–49	0.78±0.07	0.58±0.11*x	0.89±0.04*x
50–60	0.39±0.06x	0.53±0.06*	0.92±0.04*
60–65	0.33±0.08	0.51±0.08*	0.72±0.08*x

* – p<0.05 compared to the first algorithm;
x – p<0.05 compared to the previous age group.

ferences between study parameters (AV, MV and OT) are lower in male subjects aged 50–60– and 60–65– in comparison with their 30–39–year old counterparts ($p<0.05$). The statistically significant differences are seen in OT values between 40–49– and groups 50–60– and 60–65– year old male (Tab. 1).

This circumstance points to the aging decline in visual perception and informational processing capability in men.

The dynamics in women differs from that of men. The statistically significant differences between 30–49– and groups 50–60– and 60–65–year old female are observed for the OP and TPE values ($p<0.05$). The AV is decreased at age range 50–60– and 60–65– compared to 40–49– (Tab. 1).

No differences concerning the OT are seen between women in groups aged 30–39– and 40–49–years (Tab. 1).

Thus, aging involution is associated with the reduction of psychophysiological functioning, visual perception and informational processing capability in women, but these changes have not appeared to be statistically significant in men, especially between age groups 30–39– and 40–49–.

The information processing has the probability of change in the input parameters, if we understand the organization as an entropy system from chaos to higher determinism (Shannon, 1948). To study these class systems, we used the mathematical methods from the informational theory (Antomonov, 1969; Glushkov, 1963).

The organization of information processing in different age and sex groups is presented in Table 2 (men) and Table 3 (women).

The data presented in the above tables show a tendency to the increase of organization measure with changing of the algorithm. This indicates a greater determinism of psychophysiological organization during adaptation to visual information processing. A more simplified information processing structure, which includes the third algorithm, was defined as the automatically type. Statistically significant reduction of the organization measure in the second algorithm, compared to the first one ($p<0.05$), observable in the male group aged 40–49– years was the exclusion (Tab. 2).

At the same time, the organization measure of information processing decreased with increasing age as the algorithm changed. This points to a decrease of the determinism and an increase of the stochastic organization of the information processing system.

The information processing stochastic organization provides a search for links, which are needed for the formation of an optimal level of functional system (Korobeynikov, 1998, 1999). Thus, the stochastic organization of information processing system shows one of the forms of adaptation mechanisms, which prevent from aging reduction of mental capability. This conclusion confirms the adaptation theory of aging proposed by Frolkis (1993).

However, the organization measure evaluates the probability of different psychophysiological states, but it does not evaluate the operational structure of information processing.

Tab. 3. The organization of information processing in women of different age groups.

Age groups	First algorithm	Second algorithm	Third algorithm
30–39	0.78±0.05	0.73±0.06	0.91±0.03*
40–49	0.64±0.05x	0.69±0.06	0.87±0.05*
50–60	0.44±0.06x	0.56±0.07*x	0.74±0.07*x
60–65	0.61±0.10x	0.73±0.20*x	0.93±0.07*x

* – p<0.05 compared to the first algorithm;
x – p<0.05 compared to the previous age group.

Tab. 4. Coefficient a of mathematical model information processing with change of the algorithm in different age and sex groups.

Age	groups	First algorithm	Second algorithm	Third algorithm
30-39	Men	8.03	7.67	6.78
	Women	8.12	7.49	6.97
40-49	Men	8.02	7.67	7.16
	Women	7.74	7.60	6.98
50-60	Men	7.81	7.52	7.24
	Women	7.22	7.52	6.70
60-65	Men	7.62	7.43	7.15
	Women	7.12	7.54	6.98

Several authors (Sternberg, 1969; Rotenberg, 1987; Leonova, 1984; Chaichenko and Tomilina, 1995) have established the linear mathematical relation between time reaction and the number of correct information processing. The results of this investigation are opposite to their findings, but they are consistent with the data of Wickelgren (1977), presenting the speed accuracy tradeoff as a negative accelerating exponential curve. The following exponential model reflects the dependence of the latent time of solution of a test problem on the correct sequence of tasks to be performed:

$$\text{Lg } Y = a - bX \tag{7}$$

or

$$Y = \exp(a - bX) \tag{8}$$

where

Y – latent time of solving a test problem (msec),

X – number of tasks performed successfully.

According to the data of Sternberg (1969), Leonova (1984), Rotenberg (1987), Chaichenko, Tomilina (1995), coefficient *a* corresponds to the protraction of information processing (perception, processing and motor reaction). Table 4 depicts a coefficient *a* of a mathematical model information processing. The changes of task algorithm result in the decline of coefficient *a*. This dynamics corresponds to the increase of determinism of information processing organization.

Thus the reduction of perception and visual information processing protraction is connected with strength of psychophysiological organization determinism.

The increase of visual information processing protraction reflects the weakening of psychophysiological organization determinism with age.

According to conception of short-term memory activity (Chaichenko and Tomilina, 1995), the information processing has two strategies of response organization.

The first strategy – successive comparison of positive elements in short-term memory and test information by exhaustive quest. When it is necessary, long-term memory for comparison of information can be used.

The second strategy – processing by self-finishing quest with a comparison between positive elements of short-term memory, in accordance with the element in test information.

The first strategy of response organization is more efficacious than the second one, but it has higher protraction of one information processing stimulus. Due to the increase in the number of erroneous responses and the repetition of information processing stimuli, the second strategy will have a longer protraction of the information processing.

Thus our data confirm the conception of short-term memory processing (Sternberg, 1969; Band Guido and Kok, 2000). Table 5 depicts the average parameters of efficacy of visual perception and information processing capability of different age and sex groups. As it is seen in Table 5, the visual perception and information processing capability depends on the strategy of response organization.

The strengthening of determinism of information processing organization under the influence of algorithm changes was ob-

Tab. 5. Average time of solving a test problem and number of tasks performed successfully in different age and sex groups.

Age	groups	First algorithm		Second algorithm		Third algorithm	
		Average time (c)	Number of tasks	Average time (c)	Number of tasks	Average time (c)	Number of tasks
30–39	Men	0.72±0.08x	22.41±3.12x	0.62±0.08x	24.72±2.53x	0.33±0.04*	48.3±3.8*
	Women	1.13±0.13	18.60±1.83	0.81±0.12	18.43±2.15	0.39±0.04*	49.8±3.7*
40–49	Men	1.06±0.17x	20.62±2.96	0.69±0.08*	18.83±3.64x	0.43±0.06*	46.1±5.2*
	Women	0.87±0.09	17.24±1.67	0.79±0.08	18.15±1.92	0.39±0.04*	48.7±4.21*
50–60	Men	0.78±0.15	11.37±1.75x	0.74±0.16	12.72±3.01	0.54±0.06*x	34.4±3.9*x
	Women	0.70±0.09	10.93±1.34	0.81±0.11	11.12±1.64x	0.41±0.03*	38.2±3.4*x
60–65	Men	1.11±0.20x	9.22±0.86	1.10±0.90x	10.02±0.95	0.63±0.08*x	28.53±3.56*x
	Women	1.12±0.23x	8.32±1.45	1.12±0.11x	10.16±1.64	0.65±0.07*x	25.45±3.76*x

* – p<0.05 compared to the first algorithm;
x – p<0.05 compared to the previous age group.

served in age group 30–39– (Tabs 2, 3). The information processing by exhaustive quest is present in this age group (Tab. 4). The increase of visual perception and information processing capability results in such response organization (Tab. 5).

The acceleration of involution process in age group 40–49– results in decline of the perception and information processing. At the same time, the decrease of determinism of information processing organization is shown with the first algorithm performed in women and with second and third algorithms performed in men. There are changes of response organization strategy by self-finishing quest along with reduction of protraction of one information stimulus in women group 40–49– (Tab. 4). The result of this response organization shows the stabilization of visual perception and information processing capability (Tab. 5). Besides, there are no statistically significant differences between women age groups 30–39– and 40–49– for parameters: attention volume, short-term memory volume and operational thinking coefficient.

The increase of stochastic organization of visual information processing has been seen in age group 50–60– and 60–65– (Tabs 2 and 3). This finding corresponds to the strategy of self-finishing quest response in short-term memory, in accordance with the elements of test information. However, the number of correct processing stimuli decline with not reliable changes of the average time of solving a test problem in age group 50–60– and 60–65– (Tab. 5). At the same time, no changes in the operational thinking coefficient between female age groups 40–49– and 50–60– have been found (Tab. 1).

Discussion

In our previous studies the concept of psychophysiological stochastic organization in the mental activity was substantiated (Korobeynikov, 1998, 1999, 2001). According to this concept, the psychophysiological stochastic organization is a mechanism for the quest of optimal mental activity. In the process of aging involution, the adaptive-compensatory mechanisms of decline of visual perception and information processing capability protection get activated. One of these mechanisms is linked with the psychophysiological stochastic organization.

With age, the decline in perception, processing and speed reaction intensifies tension of the informational environment on older people. As a result of the negative influence of aging, the efficiency of the mental activity reduces. Decrease of the visual perception and information processing with age triggers a compensation of the psychophysiological adaptive mechanisms with the change of an algorithm. The key mechanism consists in the increase of the stochastic organization of information processing and change of the information processing structure into a self-finishing quest response.

The strengthening of determinism organization of information processing is reflecting of the aging advancement and the decline of cognitive functions, particularly the operational thinking.

The study has revealed a tendency to the increase of determinism organization along with the simplification of information processing structure. The reduction of information processing protraction is related with the high determinism of psychophysiological organization.

The increase of determinism and the change of information processing strategy reflect the psychophysiological mechanisms of life extension in the aging involution of cognitive functions.

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