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Reorganization of the Association between Intelligence and the Characteristics of Attention and Memory on Aging

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The association between intelligence and measures of the functions of the systems underlying attention and the recognition of verbal and image stimuli presented for memorization, as well as the lateral characteristics of speech memory were studied in members of an elderly age group (64.5 ± 6.3 years, $n = 83$; 43 women) and a young age group (22.0 ± 4.5 years, $n = 133$; 83 women). The rate of selection of information in conditions of conflict served as a predictor of the level of intelligence, independently of age. In elderly subjects, a higher level of intelligence corresponded to shorter executive control times, while no significant link between intelligence and functional measures of the attention system was seen in young people. Analysis of the properties of memory showed that reproduction of words addressed to the left hemisphere made a positive contribution to intelligence; in young people verbal memory for words addressed to the right hemisphere also made a contribution, while in elderly people there was a contribution from the efficiency of recognizing remembered verbal and image stimuli. Gender-linked features were seen in the age-related reorganization of the contribution of attention and memory to intelligence, with more marked changes in men.

Keywords: aging, intelligence, attention system, verbal and image memory system, hemisphere-related memory properties.

Studies of the patterns of brain aging and associated changes in cognitive processes are increasingly relevant as increases in longevity in developed countries are accompanied by increases in the risk of developing age-related dementia [Qiu et al., 2009]. Despite the fact that stable effects consisting of decreases in mental processing speed or the volume of short-term memory have been seen in elderly people [Salthouse, 1996; Matsuyoshi et al., 2014; Peich et al., 2013], it remains unclear how age-related changes in the functions of the attention systems and memory and intelligence interact. Resolution of this issue is required for an understanding of the strategies of successful adaptation to old age, as the concept that psychometric intelligence reflects the ability to adapt [Eysenck, 1995; Deary, 2008; Kanazawa, 2004] is supported by data showing that it has a positive association with health indicators [Batty et al., 2207, 2010; Deary, 2008; Hemmingsson et al., 2006]. Clarification of the pattern of age-related reorganization of cognitive functions is also required for developing cognitive training programs stimulating the cognitive resources of the the brain, as the effectiveness of these treatments cannot always be confirmed [Razumnikova, 2015; Cicerone et al., 2011; Papp et al., 2009; Slagter et al., 2007]. For example, memory training has been shown to induce not only increases in indicators of memory, but also increases in indicators of fluid intelligence [Floyd and Scogin, 1997; Jaeggi et al., 2008]. However, there is also a lack of transfer of skills acquired during training to solving other tasks or overall intelligence [Redick et al., 2013; Shipstead et al., 2012].

A positive interaction between working memory and intelligence, with a focus on studies in young people, is well known [Colom et al., 2015], though its mechanisms, including the importance of the attention system, continues to be studied. The influences of time characteristics of information processes on the interaction of fluid IQ and memory [Colom et al., 2015] can be explained using a model of working memory in which the preserved flow of visual and

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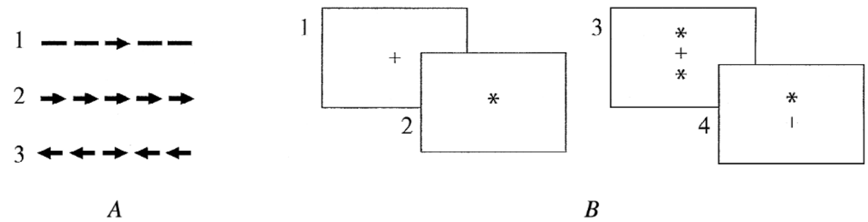

Fig. 1. Examples of stimuli (*A*) and different presentation conditions (*B*) used for identifying the functions of the attention systems. *A1*) Neutral version of target stimulus presentation; *A2*) congruent stimuli; *A3*) noncongruent version; *B1*) presentation without cue; *B2*) central cue; *B3*) double cue; *B4*) spatial cue.

auditory information is controlled by the executive attention system [Baddeley, 2000]. Evidence for the association between the rate of mental processes, working memory, and fluid IQ is provided by the results of regression analysis of these indicators, which shows that working memory is a predictor of intelligence regardless of age-related (7–19 years) changes in speed [Fry and Hale, 2000].

As regards data on the properties of attention or intelligence on aging, study results remain contradictory despite long interest in this question. Preservation of the selection of relevant information is seen in those experimental situations in which a small volume of information is presented; impairments to selection occur when the number of stimuli increases, and this effect is presumptively due to slowing of the rate of selective processes and/or limitations to the volume of attention [Groth and Allen, 2000; Madden, 1990]. Analysis of the functions of the attention system in different age groups showed that the most marked impairments were to the executive system with relative preservation of the orientational attention system [Zhou et al., 2011]. In turn, decreases in executive attention were associated with impairments to any part of the brain on aging [Luks et al., 2010]; on the other hand, the frontal cortex provides the brain's compensatory resources used for maintaining successful cognitive activity in elderly people [Buckner, 2004; Wahlund et al., 1996].

Two models are widely used for interpreting study results on changes in cognitive functions in aging and their neurophysiological correlates: process rate theory [Salthouse, 1996] and prefrontal executive control theory [West, 1996]. According to the first model, all age-related changes are based on a common mechanism of slowing of cognitive processes due to generalized impairments in the white matter of the brain; the second holds that local structural and functional changes in neural networks in the frontal cortex lead to specific impairments in the executive system of the brain, inducing various types of cognitive deficit. The process of "dedifferentiation" noted by many authors – as decreases in activity in areas of the brain specific to these functions occurring on aging, with increases in the functions of the frontal cortex and/or switching to the unspecialized hemisphere and reorganization of the activity of neural networks [Baltes et al., 1999; Juan-Espinosa et al., 2002] – is also ambiguous: it may reflect not only the realization of the brain's compensatory resources, but also pathology developing in the brain [Albinet et al., 2012].

Decreases in IQ with age can be explained in terms of decreases in the volume of working memory and increases in the time taken by selective processes [Baltes et al., 1999; Manard et al., 2014]. These processes evidently lead to decreases in, mainly, fluid intelligence; relatively crystallized views differ – they can decrease, they can remain relatively unaltered, or they can even increase [Baltes et al., 1999; Miller et al., 2009; Schaie and Willis, 1993]. A further controversial question is that of changes in hemisphere asymmetry: lateralization either weakens as a result of lower activity in the prefrontal area of the cortex involved in the processes of storing and retrieving memory traces and the inhibitory control of selective information [Daselaar and Cabeza, 2010; Reuter-Lorenz et al., 2000] or more marked reductions in right-hemisphere functions occur on aging, evidence for which is the greater decrease in spatial than verbal functions, with a decrease in the right-hemisphere gray:white matter ratio [Dolcos et al., 2002].

This diversity of views regarding the age-related reorganization of cognitive functions generates the need for further study. Thus, the aim of the present work was to address the questions: how does the interaction between the attention systems and memory – including specific hemisphere features of verbal memory – change in aging, and how are these characteristics associated with the overall level of intelligence, which can be regarded as a generalized psychometric indictor of adaptation in elderly people?

Considering data demonstrating shorter longevity in men than women [Gavrilov and Gavrilova, 1991; Stuart-Hamilton, 2010] and gender differences in the organization of cognitive processes [Vol'f, 1994; Dunst et al., 2014; Haier et al., 2005; Halpern, 2000], an additional task of the study was to identify the age-related contribution of measures of attention and memory to intelligence in men and women.

Methods. A total of 133 young people (group Y) (students in higher education, mean age 22.0 ± 4.5 years; 50 men) and 83 elderly people (group E) (staff of scientific institutions

TABLE 1. Mean Measures of Intelligence (IQ), Attention, and Memory in Young (group Y) and Elderly (group E) Subjects

Parameter	Group Y		Group E		t	p
	mean	±	mean	±		
IQ	114.7	13.7	101.2	10.8	7.62	0.0001
Attention						
RT congruent, msec	534	72	699	98	–15.52	<.001
RT noncongruent, msec	627	83	801	111	–15.52	<.001
Executive system	92	35	100	43	–1.90	0.06
Vigilance	30	32	22	44	1.64	0.10
Orientational system	22	32	38	40	–3.91	<.001
Memory						
VM_LH	19.7	5.3	18.6	6.2	1.82	0.07
VM_RH	15.7	5.1	8.7	5.5	11.38	<.001
VM syllables	7.7	1.8	6.4	2.3	5.29	<.001
IM figures	8.0	1.7	7.2	1.8	5.79	<.001
RecT syllables, sec	491	105	463	70	2.59	0.01
RecT figures, sec	547	117	443	76	8.52	<.001

RT – reaction time; VM_LH – number of words reproduced after presentation to the right ear (left hemisphere); VM_RH – presentation to the right hemisphere; VM syllables – verbal memory on recognition of remembered syllables; IM figures – image memory on recognition of geometrical figures; RecT – recognition time for syllables and figures.

aged 64.5 ± 6.3 years; 40 men) took part in the study. The study was approved by the Ethics Committee of the Research Institute of Physiology and Basic Medicine.

The rate characteristics of the selection of information and the functions of the various attention systems – executive, orientational, and vigilance – were determined using the ANT (attention network test) method [Fan et al., 2002]. The target stimulus was a central arrow (Fig. 1, *A*) whose direction had to be identified in different conditions of selecting this signal. A total of 96 stimuli were investigated. Presentation time varied over the range 400–1600 msec; a warning mark appeared on screen 100 msec before stimulus presentation. Reaction times and numbers of errors were recorded for all stimulus presentation variants using a specially developed program (by A. R. Suslov, copyright A.s. 2012617379 of August 16, 2012). These data were used to calculate measures of the functions of the three attention systems: for the executive system (RT_exec) this was the difference between the reaction times to target stimuli on presentation of noncongruent (Fig. 1, *A3*) (RTnc) and congruent stimuli (Fig. 1, *A2*) (RTc); for the vigilance system (RT_vig) it was the difference in reaction times to stimuli without cue and with a central cue (Fig. 1, *B1* and *B2*, respectively); and for orientational attention (RT_or) it was the difference in stimulus selection reaction speeds with double cues or spatial cues (Fig. 1, *B3*, *B4*). [Fan et al., 2002].

Short-term visual memory was tested using a computerized method with presentation of 10 three-letter syllables in one series and 10 simple geometrical figures in the other (stimulus presentation time was 1 sec, interstimulus intervals were 1 sec). In each series, target stimulus presentation was immediately followed by determination of whether the target stimulus was in a set of 20 objects, including 10 new stimuli or figures. The rate of recognition was individual to each subject operating in a free regime. The numbers of correct responses and the mean times to reproduce syllables or figures was recorded.

The lateral characteristics of word remembering were assessed using dichotic testing as developed previously [Vol'f, 1994]. Ten pairs of disyllabic nouns were presented synchronously in both ears. Seven lists of words were used; presentation of each was followed by a period for reproduction of the memorized words. The total number of remembered words addressed to the left ear (right hemisphere) was recorded, along with the number of remembered words addressed to the right ear (left hemisphere).

Assessment of generalized intelligence was performed using the Eysenck test [Eysenck, 1972].

Data were analyzed statistically in Statistica 13 EN number (PO# 0085E) order #310181753.

Results. Mean values for IQ and information and memory selection characteristics for the two age groups and comparisons using Student's t test are shown in Table 1. These data indicate that group E, as compared with group Y, had lower IQ, longer information section times but shorter times taken to recognize syllables and figures, along with lower information reproduction efficiency in different experimental conditions, except for reproduction of words addressed to the left hemisphere (verbal memory left hemisphere (VM_LH)). As regards the attention systems, significant differences were seen only for orientational attention (RT_or), with greater values in group E than group Y.

Age-related features in the organization of intelligence, attention, and memory were identified by factor analysis

TABLE 2. Results of Factor Analysis of Measures of Attention, Memory, and Intelligence

Parameter	Group Y				Group E			
	F1 (18%)	F2 (14%)	F3 (13%)	F4 (13%)	F1 (18%)	F2 (14%)	F3 (17%)	F4 (12%)
RTnc	**−0.666**	−0.091	0.349	0.193	**0.833**	0.194	−0.183	0.046
RT_vig	−0.056	0.047	0.468	−0.533	0.039	−0.029	0.149	**0.903**
RT_or	−0.060	−0.030	**−0.636**	0.063	0.547	−0.198	0.013	0.065
RT_exec	−0.176	−0.010	**0.751**	0.045	**0.849**	−0.043	−0.068	−0.018
VM_LH	0.151	**0.649**	0.271	0.411	−0.261	**0.800**	0.112	−0.056
VM_RH	0.040	0.187	−0.031	**−0.810**	−0.125	**−0.819**	0.158	0.076
VM syllables	0.016	**0.769**	0.017	−0.169	−0.197	0.086	**0.647**	−0.091
RecT syllables	**0.808**	−0.152	0.108	−0.023	0.022	0.292	**−0.581**	0.095
VM figures	−0.095	**0.628**	−0.132	−0.291	−0.057	0.143	**0.501**	**−0.636**
RecT figures	**0.807**	0.079	−0.073	0.167	−0.110	0.099	**−0.661**	−0.179
IQ	*0.383*	*0.324*	0.075	*−0.369*	*−0.390*	*0.255*	***0.589***	−0.01

RTc – reaction time on presentation of congruent stimuli; RTnc – noncongruent stimuli; RT_exec – measure of the functions of the executive attention system; RT_vig – the vigilance system; RT_or – the orientational system; for further abbreviations see Table 1. Numbers in bold identify the maximum loadings of factors; numbers in italics show loadings of intelligence parameters.

TABLE 3. Results of Correlation Analysis of Intelligence (IQ) with Reaction Speeds and Functions of the Attention Systems and Memory in Young (group Y) and Elderly (group E) Subjects

	Group Y		Group E	
	r	*p*	*r*	*p*
RTc	−.20	.03	−.23	.04
RTnc	**−.24**	**.01**	**−.30**	**.01**
RT_exec	−.04	.67	**−.33**	**.003**
VM_LH	.16	.07	**.28**	**.01**
VM_RH	**.25**	**.01**	.06	.61
VM syllables	.21	.02	**.35**	**.001**
IM figures	.04	.69	**.34**	**.001**
RecT syllables	.14	.11	−.25	.02
RecT figures	.14	.12	−.23	.04

Abbreviations as in Tables 1 and 2; numbers in bold show correlations at $p < 0.01$.

(with varimax rotation)for group Y and group E. For each group, the study variables were made up of four factors accounting for about 58% of the data variance in group Y and 61% in group E (Table 2), though the structures of these factors were different. For group Y, the maximal loading of factor 1 was with the time parameters of information selection and memory reproduction (RTnc, recognition time (RecT) syllables, RecT figures), while for group E the greatest loadings were with measures of the executive system (RT_exec) and RTnc. Factor 2 for group Y could be designated "memory effectiveness," as it consisted of measures of the reproduction of syllables, figures, and words addressed to the left hemisphere, while the right-hemisphere word reproduction measure had maximum loading in F4. In group E, lateralized indicators of verbal memory, with different signs, contributed to Factor 2, while measures of syllable and figure recognition contributed to Factor 3 (both effectiveness and reproduction time) as a further component of memory. In group Y, Factor 3 consisted of measures of the attention systems: executive and orientational (RT_exec, RT_or); in group E, the functions of the vigilance system (RT_vig), along with the recognition effectiveness of figures, formed F4. The IQ loading in group Y was spread over three factors: F1, F2, and F4; in group E, IQ was more represented in F3, whose structures reflects short-term memory.

Significant correlations of intelligence and the functions of the attention systems and memory obtained by factor analysis for the two age groups are shown in Table 3 and Fig. 2. These data indicate that IQ correlated negatively with RTc and RTnc and positively with the reproduction of syllables in both groups regardless of age. In addition, high-

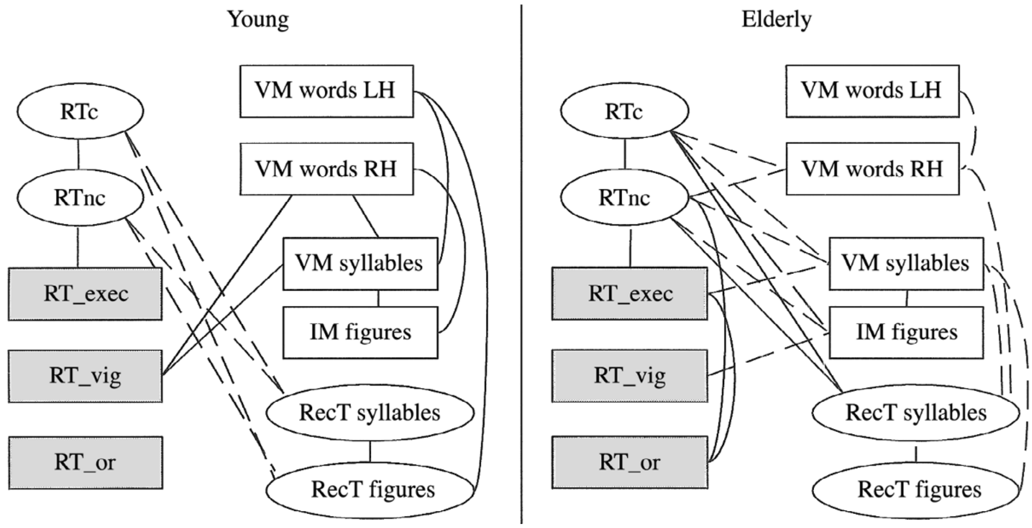

Fig. 2. Correlations between the characteristics of attention and memory for the young and old groups. Continuous lines show positive correlations and dotted lines show negative correlations; line width indicates the level of significance ($0.01 < p < 0.05$). Variables: RTc – reaction time for presentation of congruent stimuli; RTnc – noncongruent stimuli; RT_exec – measure of functions of the executive attention system; RT_vig – the vigilance system; RT_or – the orientational system, VM_LH – number of words reproduced after presentation of the right ear (left hemisphere), VM_RH – words addressed to the right hemisphere; VM syllables – verbal memory in the situation of recognizing remembered words; IM figures – image memory of recognition of geometrical figures; RecT recognition times for syllables and figures.

er IQ in group Y corresponded to a greater level of effectiveness of verbal memory for words addressed to the right hemisphere, in group E to the left; group E was also characterized by negative links between IQ and the time taken to reproduce both syllables and figures (RecT in Table 3).

The time properties of information selection (RTc and RTnc) were negatively linked with reproduction time on testing of short-term memory (RecT syllables and RecT figures) in group Y but positively in group E (RecT syllables) (Fig. 2). In turn, these measures of reproduction (RecT) in group E correlated negatively with the effectiveness of memory (VM syllables and VM words RH), while the converse applied in group Y, where the correlation was positive (RecT figures and VM words LH). The closer link between measures of information selection and its remembering in group E than group Y should be noted (20 and 14 significant links, respectively, at $p < 0.05$, or 15 and 9 at $p < 0.01$). In group Y, of the three measures of the attention system, only RT vigilance was positively linked with the effectiveness of verbal memory (VM syllables and VM words RH). In group E, significant correlations were seen between measures of the various attention systems: RT_or and RT_exec, as well as between RT_or and RTnc.

The next stage of the analysis addressed the age-related contribution of measures of the attention systems and memory to the level of intelligence using stepwise linear multiple regression. Intelligence was taken as the dependent variable and measures of attention and memory as independent variables. For each group the first analysis was individual analysis of the contributions of the rate characteristics of information selection to IQ; these were then analyzed for the three attention or memory systems; finally, an overall regression model for description of intelligence was determined.

On analysis of reaction times in situations of presentation of neutral, congruent, and noncongruent stimuli, the best regression equation was obtained using RTnc, though this parameter explained only 6% of the variance in IQ in group Y and 9% in group E (Table 4). Higher levels of intelligence corresponded to lower RTnc.

A reliable model for the description of intelligence on the basis of the properties of the attention systems could only be obtained for group E: the negative contribution of RT_exec explained 11% of the variance in IQ. In group Y, the greatest contribution among the attention systems was made by RT_vig, though this did not reach the required level of significance; the regression acquired significance on inclusion of RTnc into the model (see Table 4).

Measures of memory explained 9% of the variance of intelligence in group Y and 23% in group E. Measures of the reproduction of words addressed to the left hemisphere were significant predictors of IQ in both groups. In group E, the regression equation also included the recognition effectiveness of syllables and figures, while in group Y it included the reproduction of words addressed to the right hemisphere (Table 4).

The overall model of intelligence for group Y consisted of measures of memory identified at the first stage of regression analysis and these, along with addition of word recogni-

TABLE 4. Main Parameters of Regression Models Using Measures of the Rate of Information Selection, the Attention Systems, and Memory to Describe Intelligence in Groups of Young (group Y) and Elderly (group E) People

Parameters	β	*t*	*p*	Parameters	β	*t*	*p*
	Group Y				Group E		
Speed							
RTnc	$R^2 = 0.06; p = 0.006$			RTnc	$R^2 = 0.09; p = 0.007$		
	−0.24	−2.77	0.006		−0.30	−2.79	0.007
Attention							
RTnc	$R^2 = 0.07; p = 0.01$			RT_exec	$R^2 = 0.11; p = 0.003$		
	−0.25	−2.86	0.005		−0.33	−3.10	0.003
RT_vig	0.11	1.25	0.21				
Memory							
	$R^2 = 0.09; p = 0.002$				$R^2 = 0.23; p < 0.0001$		
VM_LH	0.18	2.12	0.04	VM words LH	0.23	2.34	0.02
VM_RH	0.26	3.09	0.002	VM syllables	0.25	2.29	0.02
				IM figures	0.22	2.08	0.04
Overall model							
	$R^2 = 0.14; p = 0.0004$				$R^2 = 0.23; p < 0.0001$		
VM_LH	0.15	1.67	0.10	RTnc	−0.20	−1.93	0.057
VM_RH	0.27	3.12	0.002	VM words LH	0.28	2.75	0.008
VM syllables	0.15	1.70	0.09	VM syllables	0.25	2.43	0.017

Abbreviations as in Tables 1 and 2.

tion effectiveness to the equation, increased the predictive capacity of the regression to 14%; however, the only significant predictor of IQ was verbal memory for words addressed to the right hemisphere (Table 4). Variables were different in group E: substitution of short-term image memory (IM figure) for RTnc provided, along with measures of verbal memory, an explanation for 23% of the variance in the level of intelligence, though the contribution of RTnc alone to variation in IQ was only at the level of a tendency ($p = 0.057$), while verbal memory is more significant in this model.

With the aim of identifying the value of the "gender" factor in the age-related reorganization of the association between intelligence and measures of attention and memory, regression analysis was performed separately for men and women. Analysis of reaction speed as a predictor of intelligence showed that this parameter was significantly linked with IQ only in women, both in group Y and in group E (Table 5); RTnc in young men was insignificant ($p < 0.3$), while in elderly men it was at the level of a tendency ($p < 0.1$; $R^2 = 0.07$). The functions of the attention systems, conversely, were significant for IQ only in men: the parameter RT_vig was significant in group Y, while RT_exec was significant in group E (see Table 5). Regression models using memory characteristics were similar in women in groups Y and E and included measures of verbal memory: lateral measures of word memory were significant predictors of IQ in both age groups, while the contribution of syllable recognition was lower. In group Y men, measures of verbal memory for words addressed to the right hemisphere was a predictor of IQ, while in men of group E this applied to words addressed to the left hemisphere, along with a positive contribution by the effectiveness of recognition of figures (Table 5).

Discussion. The greater reaction times seen on testing the functions of the attention systems in group E as compared with group Y were consistent with well known data on the slowing of mental processes in elderly people [Deary et al., 2010; Salthouse and Ferrer-Caja, 2003; Finkel et al., 2007]. The lower level of intelligence in older people seen in our study and several other reports [Kaufman, 2001; Ryan et al., 2000] are linked with impairment to the myelination of nerve fibers and the resultant slowing of the propagation of information in the central nervous system [Borghesani et al., 2013; Eckert 2011]. As shown by our studies, RT to noncongruent stimuli (RTnc in Tables 3 and 4) had a stably significant relationship with intelligence, i.e., in more complex conditions for information selection. This is consistent with results from studies of the relationship between IQ and RT in the Hick task, where there was an increase in the time required for selection of ever larger quantities of information [Sheppard and Vernon, 2008]. However, analy-

TABLE 5. Main Parameters of Regression Models Using Measures of the Rate of Information Selection, the Attention Systems, and Memory to Describe Intelligence in Men and Woman in Groups of Young (group Y) and Elderly (group E) People

Parameters	β	t	p	Parameters	β	t	p
	Group Y				Group E		
Speed							
RTnc women	$R^2 = 0.09; p < 0.012$			RTnc women	$R^2 = 0.10; p < 0.041$		
	−0.28	−2.56	0.012		−0.31	−2.11	0.041
Attention							
	$R^2 = 0.09; p < 0.044$			RT_exec men	$R^2 = 0.15; p < 0.015$		
RT_vig men	0.29	2.07	0.044		−0.38	−2.55	0.015
Memory							
Men	$R^2 = 0.16; p < 0.016$			Men	$R^2 = 0.32; p < 0.001$		
VM_RH	0.30	2.15	0.04	VM_LH	0.38	2.71	0.010
VM syllables	0.18	1.31	0.20	IM figures	0.33	2.36	0.024
Women	$R^2 = 0.14; p < 0.013$			Women	$R^2 = 0.19; p < 0.048$		
VM_LH	0.23	2.05	0.044	VM words LH	0.43	2.45	0.019
VM_RH	0.26	2.33	0.022	VM words RH	0.38	2.14	0.039
VM syllables	0.21	1.93	0.06	VM syllables	0.23	1.58	0.12

Abbreviations as in Tables 1 and 2.

sis of the age-related characteristics of regression for IQ indicated that RTnc had a near-significant link with IQ only in group E (overall model, Table 4), which is evidence for a relatively high rate of selective processes in predicting intelligence in the elderly and is consistent with previous demonstration of an age-related increase in the link between IQ and RT [Rammsayer and Troche, 2010].

Along with the age-related characteristics of the organization of the attention systems and intelligence, we found that RTnc made a significant contribution to IQ only in women (Table 4). This effect is logical if we consider data on the significant correlation of IQ with the volume of gray matter in the frontal and parietal areas of the brain in men but of white matter (in the frontal areas) in women [Haier et al., 2005]. However, a positive link between IQ and the fractional anisotropy of the corpus callosum, conversely, was seen only in men; the authors took the view that this link reflects the relationship between greater intelligence and more extensive myelination of nerve fibers supporting the effective interaction between the hemispheres [Dunst et al., 2014]. The age of the participants in this study covered a wide range – 18–50 years – so it was not clear which factor, gender or age, was of decisive significance. Comparison of regression models (see Tables 4 and 5) leads to the conclusion that the contribution of attention and memory to IQ differ not only on the basis of age, but also on the gender of the study participants.

In group E, greater IQ corresponded to a higher speed in the executive attention system (RT_exec), while in group Y only RTnc made a significant contribution. As RT_exec was defined as the difference between RTnc and RTc, the relatively large contribution of this measure to IQ in group E compared with group Y and as compared with the model based on the rate characteristics of information selection (R^2 = 0.11 and 0.09, respectively) may reflect the primary need for rapid processing of complex information at relatively low significance of the high rate for simple reactions, as already noted above. The tight link between RT measures with both IQ and measures of attention in group E (see Fig. 2 and Table 3) indicates that the rate factor of mental processes is the basis for the maintenance of high IQ in aging. The significant contribution of RT_exec to the regression for group E, explaining about 11% of the variance in IQ, is consistent with the view that effective executive control of mental functions plays a leading role as indicators of the successful deployment of cognitive reserves in aging, which is reflected in a high level of intellectual capacities [Manard et al., 2014]. In addition, factor analysis of measures of IQ and the functions of the attention and memory system, along with the regression model of intelligence including measures of the effectiveness of memory, indicate that retention of memory is a further reserve of "successful aging," independent of the rate properties of mental processes.

The most marked increase in information selection time in the orientational attention system in group E and the significant correlations with RT_exec and RTnc (Fig. 2) are evidence for the age-related reorganization of the functions of the attention system. Orientational attention is known to be linked with the functions of the neuronal systems of the posterior part of the right hemisphere [Corbetta et al., 2008; Posner and Petersen, 1990]. We also noted greater weakening of verbal memory in group E on lateralized presentation of words when addressed to the right hemisphere (see Table 2). We can therefore conclude that the decreases in attention and memory functions in elderly people are largely due to impairment of the organization of cognitive processes in the right hemisphere. This suggestion is indirectly supported by results from analysis of age-related changes in short-term verbal and image memory: on the background of a general decrease in the time taken to reproduce memory traces in group E as compared with group Y, this effect was more marked for images than for verbal stimuli (Table 2). According to the regression equation, the positive contribution of the effectiveness of the reproduction of figures to IQ points to a negative role for decreases in this indicator in elderly people. Considering views regarding the dominance of the right hemisphere in the organization of short-term image memory and the left in short-term verbal memory [Baddeley, 2003; Eng et al., 2005; Wager and Smith, 2003], our findings of decreases in these forms of short-term memory may be linked with asymmetrical compensatory processes on aging of the brain with better preserved left-hemisphere verbal functions.

Thus, along with decreased intelligence, the rate of information selection and the quantitative characteristics of its memorization are effects evidencing impaired brain functioning and various types of reorganization of these cognitive processes and can be regarded as compensatory manifestations. At the behavioral level, this compensation can be regarded as a faster response in group E on reproduction of syllables or geometric figures than in group Y, evidently decreasing the functional load on memory. The tighter connection in group E of the characteristics of attention and memory as reflections of the process of "dedifferentiation," i.e., the use of a less specialized functional organization of brain systems, may be another type of age-related adaptation of the brain [Albinet et al., 2012; Baltes et al., 1999; Juan-Espinosa et al., 2002].

As regards the gender characteristics of cognitive functions on aging, the link between IQ with the characteristics of the different attention system in men should be noted, i.e., executive control or vigilance, while the link in women was with the rate of selection of information regardless of age. In addition, the similar regression models for IQ in women in groups Y and E also constitute evidence of a less marked age-related reorganization of cognitive functions and, thus, a precondition for better adaptation in older age. However, a recent meta-analysis of results from studies of age-related changes in cognitive functions in men and women did not provide convincing evidence that gender is the factor determining the rates of these changes [Ferreira et al., 2014]. There are also data pointing to the absence of gender-related differences and that testing of some cognitive functions identifies more intense age-related differences in men, while others show this for women; these observations led to the conclusion that age, educational level, and socioeconomic status are of greater importance than gender. Given that these factors are interrelated, explanation of the role of each in the dynamics of age-related changes in cognitive processes requires further study.

Conclusions. Decreases in the level of intelligence, memory, and the rate characteristics of the selection of information in elderly people as compared with young people were accompanied by a larger contribution of reaction time to IQ in conflicting information selection conditions for older people, while the importance of measures of verbal memory in the situation of addressing words to the left hemisphere for intelligence were similar in the two groups, but reproduction of words addressed to the right hemisphere were more important in young people and recognition of remembered syllables and figures were more important in older people. The age-related differences seen in the characteristics of the attention systems and memory and intelligence support the "dedifferentiation" hypothesis in the organization of cognitive functions in elderly people and suggest that aging is associated primarily with degradation of the functioning of the right hemisphere, while constant verbal activity promotes better left-hemisphere retention of verbal memory.

The age-related reorganization of attention, memory, and intelligence is different in men and women, with more marked changes in men. Regardless of age, the characteristics of the attention system made a greater contribution of intelligence, while in women this applied to the rate of selection of noncongruent stimuli.

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