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Procedia - Social and Behavioral Sciences 140 (2014) 440 – 446

Procedia
Social and Behavioral Sciences

PSYSOC 2013

Age Dynamics Of intelligence in Adolescence And Early Adulthood

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Abstract

Our study aimed to analyse age-specific IQ changes in adolescence and early adulthood and to identify structural changes in intelligence at three stages of IQ of development - 14, 15 and 19-20 years. To estimate age-specific intelligence dynamics WISC, WIAS, SPM, EFT and academic achievement were used. It was shown that stabilization of intelligence as an integrated system is not simultaneous, but it begins at the stage of growth of intelligence through sequential stabilization of its partial functions. It was found age specific features of intelligence development: 1) a significant integration of verbal intelligence functions occurs from 14 to 15 years, which remains unchanged from 15 to 19-20 years; 2) against the background of stabilization of verbal functions from 15 to 19-20 years, the degree of cross-functional interactions considerably increases. The unity of verbal and nonverbal mechanisms of analytical-synthetical activity is formed. The findings revealed that the formation of intelligence structures determining the productivity of intellectual activity derives from chaos to order, from forms of relative globality and undifferentiatedness toward new forms of ever-increasing differentiation and hierarchical integration.

Selection and peer-review under responsibility of the Organizing Committee of PSYSOC 2013.

Keywords: Cognitive development, adolescence, early adulthood, age-related changes in the structure of intelligence

1. Introduction

It is well known that intelligence throughout life varies irregularly. The largest increase in human IQ is observed from 2 to 12 years and at the age of 19-20 IQ reaches its maximum. Then there is a period of stabilization of intelligence. The productivity of intellectual activity begins to decline since 30-34 years [Thurstone & Thurstone, 1941; Piaget, 1951; Ponomaryov, 1999; Kaufman, Lichtenberger, 2006: Hunt, 2011].

From a psychological point of view, the purpose of intelligence is to create order out of chaos [Kholodnaya, 2002]. To perform this function, the intelligence must have a certain structure to match individual's needs according

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Selection and peer-review under responsibility of the Organizing Committee of PSYSOC 2013.
doi:10.1016/j.sbspro.2014.04.450

to the objective reality. Therefore, a special interest is of the study of age-related changes in the structure of intelligence in those age ranges, when intelligence begins to reach its maximum, i.e., at the age of 14-20.

Our study is aimed to analyse age-specific IQ changes in adolescence and young people and to identify structural changes in intelligence at three stages of IQ of development - 14, 15 and 19-20 years.

2. Procedures and Methods

2.1. Participants

Participants of the experiment were Russians (388 persons), including 239 second-year students (19-20-years-old, 64% female) from the Chemistry Department (Ural State University), 77 teenagers aged 14 years (58.4% girls) and 72 teenagers aged 15 years (62.5% girls).

2.2. Methods

To estimate age-specific intelligence dynamics, we made use of Wechsler's intelligence test (WISC, WIAS), J. Raven's intelligence test (Standard Progressive Matrices), Test of G. Witkin "Embedded Figure Test" (field dependence / field independence) and academic achievement.

Raven's Standard Progressive Matrixes (SPM) is a well-validated measure of fluid reasoning ability (gF) [Carpenter, Just, & Shell, 1990]. The Raven's Standard Progressive Matrixes contain 60 nonverbal items [Raven, Court, Raven, 1992]. Each item consists of 3 × 3 matrix with a missing piece to be completed by selecting an answer from six or eight alternatives.

Wechsler Adult Intelligence Scale is used for individuals aged from 16 to 89. The WAIS is a general test of intelligence measuring person's global capacity to act purposefully, to think rationally, and to deal effectively with environment [Wechsler, 1981]. The Russian version of the WAIS [Filimonenko & Timofeev, 1995] is an adaptation of the American version [Wechsler, 1955]. It consists of 11 subtests: Information, Comprehension, Arithmetic, Similarities, Digit Span, Vocabulary, Coding, Missing details, Block Design, Object Assembly, Picture Completion, Digit Symbol, and Picture Arrangement. *Wechsler Intelligence Scale for Children* [WISC; Wechsler, 1991] is used for young people under 16 years old [Russian version WISC by Filimonenko, Timofeev, 2006].

"Embedded Figure Test" [EFT, Oltman, Raskin, Witkin, 1971]. The Russian version of EFT consists of twelve problems. This test is administered individually and requires detecting a simple embedded figure in a more complex one. The score determines a mean time (sec) of solving problems. The higher is the mean time, the higher is the degree of field dependence.

Academic achievement was estimated as a mean score on chemistry (0-5 points). 5 points corresponds to an excellent knowledge, 0-2 points corresponds to poor knowledge

Mathematical data processing was carried out by using the ABM SPSS software package 20. Statistical processing techniques of empirical data included descriptive statistics; parametric methods for identifying differences and relationships: correlation analysis and factor analysis.

3. Results

3.1. Comparative analysis of intelligence ın adolescence and early adulthood

According to our data (Table 1, Table. 2), a significant increase in indicators of field-independence as well as in indicators of verbal, nonverbal, and general intelligence (WISC, WIAS) was observed from 14 to 19-20 years. However, the findings on Raven's test showed that IQ did not change from 14 to 15 years, but significantly increases towards 19-20 years (T = - 4.584***). A similar pattern was detected for the subtests "Arithmetic" and "Vocabulary".

The indicator "Object Assembly" significantly increases from 14 to 15 years (T = -3.540 ***), and then significantly decreases from 15 to 19-20 years (t = 6.506 ***). Of particular interest is the fact that the indicator Block Design remains unchanged at all the stages of development from 14 to 19-20 years. Thus, Block Design as an

indicator of fluid intelligence is insensitive both to age and to educational influences.

Table 1. Age dynamics of intelligence in adolescence

№	Indicators	14-year-olds		15-year-olds		Independent - Samples T-test
		Mean	Std. deviation	Mean	Std. deviation	
		WISC				
1.	Information	9.83	2.84	11.13	2.93	-2.738**
2.	Comprehension	7.36	2.04	9.32	1.76	-6.282***
3.	Arithmetic	10.12	2.777	11.00	3.423	-1.722
4.	Similarities	12.01	2.868	14.10	3.145	-4.205***
5.	Digit Span,	7.29	3.132	9.07	3.164	-4.438***
6.	Vocabulary	9.69	2.413	9.72	1.900	-0.096
7.	Coding	11.74	2.468	13.44	2.726	-3.991***
8.	Missing details	6.60	2.12	9.90	2.47	-8.736***
9.	Block Design	12.90	2.86	13.68	2.65	-1.736
10.	Picture Completion	10.13	2.78	11.15	2.91	-2.188*
11.	Object Assembly	12.37	3.607	14.49	3.67	-3.540***
	IQ verbal	89.39	10.22	96.45	11.48	-3.944***
	IQ nonverbal	96.27	12.12	107.21	12.06	-5.497***
	IQ general	95.69	9.99	106.41	10.56	-4.759***
	Raven's SPM	46	8.19	48.67	7.11	-1.903
	Embedded Figure Test, sec	59.54	24.03	40.89	17.36	4.759***
	Academic achievement, chemistry, scores	3.91	0.64	3.74	0.66	1.511

Sig. (2-tailed)* $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

Table 2. Comparative analysis of intelligence in adolescence and early adulthood

№	Indicators	15-year-olds		19-20-year-olds		Independent - Samples T-test
		Mean	Std. deviation	Mean	Std. deviation	
		WISC		WAIS		
1.	Information	11.13	2.926	13.47	2.221	-6.285***
2.	Comprehension	9.32	1.759	14.59	2.710	-19.431***
3.	Arithmetic	11.00	3.423	12.45	2.383	-3.372***
4.	Similarities	14.10	3.145	14.97	2.495	-2.171*
5.	Digit Span,	9.07	3.164	10.91	2.692	-4.478***
6.	Vocabulary	9.72	1.900	13.97	2.060	-16.318***
7.	Coding	13.44	2.726	17.13	2.462	-10.273***
8.	Missing details	9.90	2.473	12.33	1.686	-7.787***
9.	Block Design	13.68	2.653	13.53	2.434	0.426
10.	Picture Completion	11.15	2.910	12.10	1.459	-2.676**
11.	Object Assembly	14.49	3.666	11.48	2.527	6.506***
	IQ verbal	96.449	11.475	122.405	9.035	-17.617***
	IQ nonverbal	107.213	12.064	122.209	8.285	-9.869***
	IQ general	106.410	10.561	123.719	7.647	-12.924***
	Raven's SPM	48.676	7.112	52.880	5.487	-4.584***
	Embedded Figure Test, sec	40.895	17.358	33.272	17.392	3.240**
	Academic achievement, chemistry, scores	3.748	0.6602	3.829	0.626	-0.913

Sig. (2-tailed)* $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

This can be explained by the fact that the formation of visual analysis ability occurred at an earlier age. It is probable that before 14 years this process had been completed, and then it remains relatively constant, at least for the age groups under study.

It should also be noted that non-verbal intelligence changes by more higher rates and its level is higher than the level of verbal intelligence in adolescents aged 14 and 15. However, from 15 to 19 years the indicator of verbal intelligence changes with a higher rate and the indicator values of verbal and non-verbal intelligence are equalized (IQ verbal = 122.4; IQ nonverbal =122.2).

3.2. Factor analysis of intelligence ın adolescence and early adulthood

As a rule, factor analytic studies yield three factors: Verbal Comprehension, Perceptual Organization, and Freedom from Distractibility. The Verbal Comprehension factor is an indicator of crystallized intelligence (gC) and comprises Information, Comprehension, Vocabulary, and Similarities. The Perceptual Organization factor is regarded as a measure of fluid intelligence (gF) and consists of Block Design, Object Assembly, and Picture Completion. The Freedom from Distractibility factor is an indicator of working memory (gW) and consists of Digit Span and Arithmetic [Parker, 1983; Leckliter, Matarazzo, & Silverstein, 1986; Kaufman, Lichtenberger, 2006; Hunt, 2011].

Factor analysis of intellectual indicators at three different ages (14, 15 and 19-20 years) resulted in the extraction of 4 factors explaining 62.431%, 67,269% and 60,937% of general variance for each age group. The content of these factors indicates that from adolescence to youth there are significant changes in the structure of intelligence (Table 3, 4 & 5).

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Table 3. The results of factor analysis of intelligence in 14-year-olds

Rotated Component Matrix[a]				
	Component			
	1	2	3	4
Information	0,852			
Similarities	0,799			
Arithmetic	0,694			
Picture Completion		0,813		
Block Design		0,771		
Coding		0,555		
Object Assembly			0,745	
Comprehension			0,647	
Digit Span			0,593	
Vocabulary				0,739
Missing details				-0,665
Extraction Method: Principal Component Analysis.				
Rotation method: Varimaks with Kaiser normalization.				
a. Rotation converged for 7 iterations				

As can be noted, at the age of fourteen (Table 3) Verbal Comprehension Factor comprises only two out the four indicators (Information and Similarity). Indicators of Perceptual Organization factor (Block Design and Object Assembly) appeared to be scattered on different Components (Component 2nd & 3rd) as well as the indicators of Freedom from Distractibility factor (Digit Span and Arithmetic.) are located on Component 1 and Component 3. Such a distribution of indicators can testify to undifferentiatedness of mental functions, i.e. "chaos" in the organization of mental experience in 14-year-olds.

Tendency to structuring in intelligence is observed at the age of fifteen (Table 4). It manifests itself in the fact that three of the four indicators (Information, Similarities, and Comprehension) were combined into a single Verbal Comprehension factor. However, the lack of structuredness of intelligence is preserved so far.

Table 4. The results of factor analysis of intelligence in 15-year-olds

Rotated Component Matrix[a]				
	Component			
	1	2	3	4
Digit Span	0,855			
Similarities	0,822			
Information	0,782			
Comprehension	0,718			
Picture Completion		0,840		
Missing details		0,627		
Block Design		0,570	0,518	

Vocabulary		0,744	
Arithmetic		0,557	
Object Assembly			0,809
Coding	0,516		-0,654
Extraction Method: Principal Component Analysis.			
Rotation method: Varimaks with Kaiser normalization.			
a. Rotation converged for 6 iterations			

Table 5. The results of factor analysis of intelligence in 19-20-year-olds

Rotated Component Matrix[a]				
	Component			
	1	2	3	4
Vocabulary	0,793			
Similarities	0,759			
Comprehension	0,697			
Information	0,691			
Block Design		0,820		
Object Assembly		0,777		
Arithmetic			0,460	
Missing details				
Digit Span			0,824	
Picture Completion				0,789
Coding				
Extraction Method: Principal Component Analysis.				
Rotation method: Varimaks with Kaiser normalization.				
a. Rotation converged for 6 iterations				

At the age of nineteen we observe a classic pattern of structural organization of intelligence in terms of indicators of the WAIS test. This fact testifies to a clear differentiation of cognitive functions. The data obtained suggest that the structures of intelligence are formed at early youth age as a basis for further productive of intellectual activity

3.3. Correlation analysis of intelligence ın adolescence and early adulthood

Correlation analysis of the indicators of intelligence testifies that the transition from one stage of age development to another, in parallel with an increase in the differentiation of functions, integration of functions increases (Table 6). An increase in mental functions differentiation was confirmed from 14 to 15 and further to 19-20 year-olds both by the data of factor analysis and by a decrease in reaction time at the given age stages under study [Volkova, 2011].

These data serve as a basis for conclusions about the growth of integration of functions from the results of correlation analysis (Table 7). As can be noted, the percentage of significant correlations amounts to 36.36 at the age of fourteen; 47.27 at the age of fifteen and 58.18 at the age of nineteen-twenty.

Table 6. A number of significant correlations between intellectual indicators at different stages of age development

Participants	Total intercorrelations between the indicators of intelligence (55)	Number of intercorrelations between the indicators of verbal intelligence (15)	Number of intercorrelations between the indicators of non-verbal intelligence (10)	Number of intercorrelations between the verbal and non-verbal indicators of intelligence (30)
14-year-olds (77 people)	20 (36.36%)	7 (46.6%)	4 (40%)	9 (30%)
15-year-olds (72 people)	26 (47.27%)	12 (80%)	4 (40%)	10 (33.3%)
19-20 year-olds (234 people)	32 (58.18%)	12(80%)	5(50%)	15(50%)

At the same time we found a great deal of interesting age specific features (Table 7).

1. A significant integration of verbal intelligence functions (from 46 to 80%) occurs from 14 to 15 years, which remains unchanged from 15 to 19-20 years.

2. Against the background of stabilization of verbal functions from 15 to 19-20 years, the degree of cross-functional interactions considerably increases (from 33 to 50%).

3. The degree of integration of nonverbal intelligence functions remains unchanged in the range from 14 to 15 years and then slightly increases towards 19 years (50%).

A comparison of the number of significant intercorrelations of each Wechsler intelligence test indicators with the qualitative analysis data of the content of subtests, revealed certain peculiarities in age-specific cognitive activity (Table 7).

Table 7. A number of significant intercorrelations between the intelligence at different age stages

№	Indicators	The stages of age development		
		14-year-olds	15-year-olds	19-20 -year-olds
1.	Information	5	5	8
2.	Comprehension	3	6	4
3.	Arithmetic	3	5	7
4.	Similarities	4	7	8
5.	Digit Span,	6	8	5
6.	Vocabulary	1	3	7
7.	Coding	1	2	3
8.	Missing details	1	5	7
9.	Block Design	5	7	8
10.	Picture Completion	5	4	0
11.	Object Assembly	5	0	7

In particular, at the age of fourteen a pivotal factor of cognitive activity is working memory (Digit Span had 6 intercollerations). A similar picture was observed in case of nonverbal analysis of event sequence (Picture Completion), visual analysis and visual synthesis (Block Design & Object Assembly) (all had 5 intercollerations). Categorial generalization (Similarity) had only 4 intercorrelations.

At the age of fifteen the role of working memory increases much more (Digit Span had 8 intercorrelations).

The visual analysis goes to the foreground (Block Design had 7 intercollerations), while the nonverbal analysis of event sequence has 4 intercollerations. The visual synthesis (Picture Completion had 0 intercollerations) is replaced by categorial generalization (Similarity had 7 intercollerations).

At the age of 19-20 the role of working memory decreases significantly and mental activity involving visual analysis (8 intercollerations), visual synthesis (7 intercollerations) and categorical generalization (8 intercollerations) goes to the foreground. Thus, the unity of verbal and nonverbal mechanisms of analytical-synthetical activity is formed.

4. Conclusions

By generalizing the results of comparative analysis, factor analysis and correlation analysis we can conclude that the formation of intelligence structures determining the productivity of intellectual activity derives from chaos to order, from states/forms of relative globality and undifferentiatedness toward new states / forms of ever-increasing differentiation and hierarchical integration.

In the process of age-related development, there is a certain sequence in changes of the ratio of stabilization and domination periods in cognitive functions. According to our data, the stabilization of nonverbal features and the domination of verbal intelligence functions are observed from 14 to 15 years. The stabilization of verbal functions of intelligence and an increase in cross-functional interactions occurs from 15 to 19-20 years. Thus, the stabilization of intelligence as an integrated system is not simultaneous, but it begins as early as at the stage of growth of intelligence through sequential stabilization of its partial functions.

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