DE GRUYTER
OPEN

DOI 10.1515/jped-2015-0002 JoP 6 (1): 25 – 41

The relationship between fluid intelligence and learning potential: Is there an interaction with attentional control?[1]

Marta Filičková, Ivan Ropovik, Monika Bobaková, Iveta Kovalčíková

Abstract: The main aim of the study was to explore the relationship between fluid intelligence (gf), attentional control (AC), and learning potential (LP), and to investigate the interaction effect between gf and AC on LP. The sample comprised 210 children attending the fourth grade of a standard elementary school. It was hypothesized that the extent of the association between gf and LP depends on the level of attentional control, so that a low level of AC would weaken or possibly break that link, while a high level of AC would facilitate the employment of fluid general ability in learning situations. The results show that there was a moderate relationship between the measures of gf and LP, while gf was not found to be related to AC. Regarding the hypothesized interaction effect, the data suggested that the relationship between learning potential and fluid intelligence is invariant regarding the level of attentional control in the sample. Possible reasons for the lack of a moderation effect are discussed.

Keywords: fluid intelligence, attentional control, learning potential, interaction effect.

---

[1] This work was supported by the Slovak Research and Development Agency under grant number APVV-0281-11.

The concept of learning potential has captured the attention of experts in cognitive psychology (Sternberg & Grigorenko, 2002; Wiedl, 2003), educational psychology (Resing, 2013) as well as cognitive education (Džuka & Kovalčíková, 2008; Kovalčíková, 2010). Learning potential, known also as cognitive modifiability (Feuerstein, Rand, Hoffman, & Miller, 1980), the ability to learn, latent learning capacity (Kovalčíková, 2009) and testing the limits (Carlson & Wiedl, 1979), can be understood as an indicator of what a child is able to do or learn if the conditions are adjusted. This concept is based on Vygotsky's theory of the zone of proximal development (ZPD) (see Vygotsky, 1962) and Feuerstein's theory and subsequent development of the learning potential assessment device (LPAD) and instrumental enrichment (IE) (see Feuerstein, Rand, & Hoffman, 1979; Feuerstein, Rand, Hoffman, & Miller, 1980).

Budoff (1987) refers to learning potential as the ability to improve cognitive performance as a result of training. Similarly, Taylor (1992) defines learning potential as the underlying fundamental aptitude or capacity to acquire and master novel intellectual or cognitively demanding skills. This aptitude is demonstrated through improvements in performance as a response to cognitive mediation, teaching, feedback, or repeated exposure to the stimulus material. Several studies agree that learning potential predicts cognitive functioning, especially problem solving skills (Wiedl, 1999; Wiedl, Schottke, & Calero-Garcia, 2001), the acquisition of working skills (Sergi, Kern, Mintz, & Green, 2005), better results in cognitive rehabilitation (Wiedl & Wienobst, 1999), rehabilitation readiness (Fiszdon et al., 2006), and so forth.

Learning potential assessment can be understood as an assessment method targeting basic cognitive abilities and potential. The concept of learning potential lies behind dynamic testing and assessment. Dynamic testing (and dynamic assessment) (Budoff, 1987; Feuerstein, Rand, & Hoffman, 1979; Sternberg & Grigorenko, 2002, Lidz, 2000; Tzuriel, 2000) has the potential to reveal the latent ability of the person tested. The dynamic test is used to measure learning potential. In comparison to traditional cognitive ability tests (for example, IQ tests), the dynamic test provides immediate feedback, prompts and training enabling children to show progress when solving cognitive tasks (Elliott, Grigorenko, & Resing, 2010; Haywood & Lidz, 2007). Dynamic testing is based on the premise that human abilities develop in activities where individuals are led and supported by other people using the cultural means available.

The dynamic test is structured in a particular way; it consists of a pretest, the training phase and a posttest. Thus dynamic testing is an assessment method in which the training phase is incorporated into the testing process. Aiming to assess the cognitive (learning) potential of a child, the dynamic test takes into consideration what the child can learn during a short period of time.

Theoretical Developments

The aim of this section is to cover the variables considered in the present study. It outlines the arguments suggesting there is a relationship between attentional control and fluid intelligence and how this interaction may influence the level of learning potential in children.

Linking learning potential (LP) and fluid intelligence (gf) Learning potential has already been described above as the ability to improve cognitive performance as a result of training. On the other hand, fluid intelligence refers to innate intelligence that can be related to all kinds of problem solving. According to Cattell (1971), it is related to how well an individual perceives complex relations, forms concepts and engages in abstract reasoning.

Learning potential (LP) and fluid intelligence (gf) seem to be diverging, since the former is a measure of what a child can learn with help, while the latter measures what a child knows at the moment. However, depending on the point of view, both LP and gf are considered significant predictors of professional and academic achievement. LP is measured by dynamic assessment, which, according to Haywood and Lidz (2007), is an especially useful method when “normative testing is likely to yield low scores and consequent pessimistic predictions of future learning effectiveness and school achievement” (p. 3). Gf is understood as a fundamental abstract reasoning and concept formation capacity that an individual applies to novel problems (Jensen, 1998). It is also used in developing new abilities and in the acquisition of new knowledge.

Both LP and gf share certain common traits. In 2005, a study by Swanson and Howard found a correlation of .36, p<.001 between intelligence score and gain score in a dynamic test. As Stevenson (2012) points out, recent research indicates that fluid reasoning ability may be more influenced by learning experiences than one would expect. For instance, there are considerable individual differences in the effects of retesting and training on fluid reasoning tasks in both adults (Freund & Holling, 2011) and school children (Mackey, Hill, Stone, & Bunge, 2011). Moreover, the results of dynamic testing studies correspond with research on retesting and training effects of fluid intelligence, since generally positive training effects are found, with large individual variation in improvement (for instance, Fabio, 2005; Jeltova et al., 2011; Swanson & Lussier, 2001; Sternberg et al., 2007).

Link between learning potential (LP) and attentional control (AC) Attentional control (AC), a crucial working memory (WM) mechanism, consists of focusing attention on the correct task-set and blocking distraction. Baddeley and Hitch (1974) proposed a model to describe the structure of working memory capacity in which the central executive system is considered responsible for controlling attention and information processing, which in turn regulates the operation of two domain specific systems, the phonological loop and visuospatial sketchpad (Stevenson, 2012).

As perceived by Alloway (2009), AC as part of WM is considered a good indicator of children's learning potential (LP). In a study by Stevenson et al. (2013), WM efficiency and performance on an analogical reasoning dynamic test were both positively related to maths and reading achievement. Thus, both measures constituted unique predictors of concurrent and subsequent achievement in maths and reading.

Linking fluid intelligence (gf) and attentional control (AC) Attentional control (AC), a working memory (WM) component, is considered to lie behind general fluid intelligence (gf). Executive-attention theory holds that the advantage of intelligent people dwells in their ability to focus on relevant information and to effectively block the distracters in WM operations (Engle & Kane, 2004). Studies by Conway et al. (2002) and Kane et al. (2004) found that the variables reflecting AC strongly correlated with gf. Similarly, the results of a Finnish study (Hotulainen, Thuneberg, Hautamäki, & Vainikainen, 2014) showed that AC contributed to scientific reasoning (gf), which in turn explained the greatest proportion of school achievement. The Finnish researchers discovered that the Attention Concentration Test (ACT), a measure of AC, seems to be a useful tool in assessing exceptional academic achievement in students. Their study suggests that if a student has poor AC it is nearly impossible for them to become a high achiever in scientific reasoning.

However, there are other studies (for example, Schweizer, 2010; Unsworth and Spillers, 2010) that ascribe only a small amount of gf variance to AC, 7% to be precise. Similar results were obtained by Chuderski (2014) who examined the role of AC in predicting gf. According to his findings, AC was a weak predictor of gf, explaining less than one third of variance accounted for by capacity.

Blair (2006) views WM and gf as separate but highly related constructs, and suggests that the mechanism behind this relationship is AC – an ability that is dependent on the normal functioning of the prefrontal cortex. In a recent meta-analysis, Ackerman, Beier, and Boyle (2005) pointed out that working memory and general fluid intelligence have on average 20% variance (but see Kane et al., 2004). This modest overlap suggests that these two constructs are not synonymous (see also Conway, Kane, & Engle, 2003).

Present Study

All three concepts examined in our study are considered crucial for school achievement. Much of learning in school is regarded as a form of analogical reasoning, which is often assessed using classical analogy problems (for example, matrices). The ability to solve such analogy problems, a measure of fluid reasoning, has been shown to be a good predictor of school achievement in both the reading (Ferrer et al., 2007; Stanovich, Cunningham, & Feeman, 1984) and maths domains (Primi, Ferrão, & Almeida, 2010; Taub, Floyd, Keith, & McGrew, 2008).

The nature of learning potential itself implies an ability to predict subsequent performance and educational success. A body of evidence demonstrates that the measure of learning potential correlates with school performance (Elliot & Lauchlan, 1997; Haywood, 1997). Similarly, a study by Resing, Stevenson and Bosma (2012) revealed that dynamic test scores were the best predictors of school achievement.

Also, attention control has a significant place in education. Children need to know what is most important to focus on when learning. There is considerable evidence that the executive attention network is of great importance in the acquisition of school subjects such as literacy (McCandliss et al., 2003). The findings of Alloways' (2010) study revealed "that children's working memory skills at 5 years of age were the best predictor of literacy and numeracy six years later. Working memory thus seems to be a more powerful predictor of subsequent academic success than IQ taking into account children at the start of formal education.

All in all, the results of research by Swanson and Howard (2005) show that dynamic testing measures, in addition to working memory (WM) and fluid intelligence (gf), improved the prediction of academic achievement (both mathematics performance and reading skills performance, word recognition in particular). In our research, we therefore take a closer look at the relationship between fluid intelligence and learning potential (LP), taking into account attentional control (WM component).

Understanding the role of attentional control in academic achievement, we anticipated that attentional control would positively correlate with both fluid intelligence and learning potential. Furthermore, we expected that this AC would act as a moderator of the relationship between gf and LP.

It was hypothesized that there is an interaction affecting the strength of relationship between fluid intelligence and learning potential. Namely, it was expected that the product of fluid intelligence and attentional control significantly predicts learning potential. If true, the level of attentional control could affect the link between fluid intelligence and learning potential in such a way that a low level of attentional control would weaken or possibly break that link, while a high level of attentional control would facilitate the use of fluid general ability in learning situations. Another likely option is that attentional control would act as a "hygienic variable", where a certain level of attentional control is needed for the link between fluid intelligence and learning potential, but where raising the attentional control above that level does not strengthen it any more.

Method

Participants

The sample comprised 210 children from the standard population who were attending primary school. Their mean age was 9 years and 7 months. The children were individually tested by trained psychologists. Since this study was a part of large-scale research involving the construct validation of two test batteries, it took three sessions per child to administer the test batteries.

Measures

Learning potential (LP) To measure learning potential, the AnimaLogica dynamic test was used (see Stevenson, 2012). The test is a typical dynamic one and each child was provided with graduated prompts during the training phase. This test, aimed at children aged 5 to 12, is based on the principle of analogical reasoning. The test comprises specific figural analogies (A:B::C:D) in the form of 2x2 matrices where the objects are familiar animals. Using a computer mouse, the children are supposed to drag and drop the animal figures into an empty box in the lower quadrant of the matrix. The animal figures represent six possible transformations. Each analogy consists of two animals, available in three colours (red, yellow or blue) and two sizes (large or small). The orientation (facing left or right) can be changed by clicking on the animal figure. Quantity (one or two) can be specified by dragging the desired number of animal figures into the empty box. The animal figures can be positioned at the bottom, middle or top of the empty box.

In order to statistically isolate learning potential, an unstandardized residual score was computed (AnimaLogica posttest score regressed on the WJ Verbal Analogies subtest). By subtracting the predicted Animalogica posttest score, the observed score could be “purified” and the variance accounted for by the factor of analogical reasoning partialled out. The measures obtained from the residual score were thus used as the operational definition for the level of learning potential.

Attentional control (AC) As implied by current models of attention processes (for example, Banich et al., 2000; Carter, Mintun, & Cohen, 1995; MacDonald et al., 2000; Posner & Dehaene, 1994), attentional control is associated with inhibitory functions. More specifically, attention processes are responsible for selecting task-relevant representations and actions (Milham et al., 2002). The concept of attentional control was thus operationally defined by the score in the third subtest from the D-KEFS Color-Word Interference Test (C-WIT) (Delis, Kaplan, & Kramer, 2001), since its score reflects the level of both aspects of attentional control, namely selection and inhibition. Data gathered by West and Alain (2000) also support the idea that disruptions in attentional control processes contribute to poor performance in C-WIT.

The C-WIT test is based on the Stroop effect, that is, it is an outcome of our mental (attention) vitality and flexibility and a demonstration of interference in the reaction time of a task. When the meaning of a word is combined with a contradictory message, such as the colour of the word, it interferes with processing, causing delays and errors in the response. C-WIT measures the ability to inhibit a dominant and automatic verbal response. In the third subtest – inhibition – the subject must name the colour in which the word is presented, while ignoring the printed word. Thus, incongruence between the word's colour and identity (for example, the word "blue" presented in red) requires inhibition and response selection. The D-KEFS C-WIT Inhibition subtest was chosen since its score reflects the level of both aspects of attentional control, namely selection as well as inhibition.

Fluid intelligence (gf) In order to measure the level of fluid intelligence (gf), we used the Woodcock-Johnson battery. The score on tests representing quantitative reasoning ability were used as operational definition of fluid intelligence. The WJ Quantitative Reasoning subtest is a classic fluid intelligence (gf) measure, usually having one of the highest gf factor loadings in empirical studies. Children were required to analyse puzzles to determine the missing components, a numerical sequence, and a two-dimensional numerical pattern. The children's answers in the Woodcock-Johnson battery were scored metrically.

Preliminary analyses

The data analysis was preceded by an examination of observed variables in terms of their distributional properties (mean, standard deviation, skewness, kurtosis, outliers and missing values). No more than 2% of the data was missing and the imputation of the missing data was carried out using the maximum likelihood method. The subsequent visualization of the distributions (histograms and probability plots) indicated departures from normality in all the variables observed (especially in terms of skewness). These indications were confirmed by a significant Kolmogorov-Smirnov test of normality in each case. Subjecting the variables to non-linear transformations ($\log(x+1)$ or $\sqrt{(x)}$) did not bring about the expected effect. In the next step, a matrix of z-standardized data ($M = 0$, SD = 1) was created in order to identify univariate outlying values. Severe outliers that were probably due to errors in administration were replaced by a value of two standard deviations from the mean ($M \pm 2$SD).

Despite several univariate outliers, no subject was identified as being a multivariate outlier (based on Cook's distance) that could potentially bias regression coefficients. According to the Durbin-Watson test, the assumption of independent error variances was met ($d = 1.87$). So was the assumption of homoscedasticity in the variance of residuals with regard to the outcome variable (evaluated by plotting the standardized predicted values against the standardized residual values). With a sample size of $N = 210$ and given the acceptable Type I and II error rates ($\alpha = .05$ and $\beta = .20$, respectively), there is sufficient statistical power to detect an effect of a magnitude as low as

r = .19. It can be concluded that the data meet the assumptions of multiple regression analysis. At the same time, it can be expected that the defined regression model will generalize well.

Results

The distribution characteristics of the variables undergoing further analysis can be found in Table 1. To examine the associations between the variables employed in the present study, that is, reflecting the magnitudes of bivariate relationships, Spearman's non-parametric correlations were computed (Table 2).

Table 1
Descriptive statistics

	Min	*Max*	*M*	*SD*	*Skewness*		*Kurtosis*	
						SE		*SE*
WJ Quantitative Reasoning	13	34	26,1	3,7	-0,49	,17	0,49	,33
D-KEFS Inhibition	40	180	84,9	26,6	1,40	,17	2,23	,33
Animalogica Posttest	1	69	53,5	9,2	-1,37	,17	4,36	,33
WJ Verbal Analogies	0	13	6,1	1,9	0,20	,17	1,80	,33

Note. Min = minimum, *Max* = maximum, *M* =mean, *SD* = standard deviation, *SE* = standard error.

Table 2
Spearman's Correlations (r_s)

		[1]	[2]	[3]	[4]
[1] WJ Quantitative Reasoning	*rs*	1			
	p	.			
[2] D-KEFS Inhibition	*rs*	-.15*	1		
	p	.03	.		
[3] Inhibition*Quant_Reasoning	*rs*	-.21**	.13	1	
	p	.03	.06	.	
[4] AnimaLogica Post Residual	*rs*	.30**	-.10	-.11	1
	p	.00	.16	.11	.

In order to test the hypothesized interaction effect, the procedure adopted by Aiken and West (1991) was followed. The variables were centred (mean subtracted) and an interaction term (Inhibition x Quant_Reasoning) was computed.

Overall, the postulated multiple regression model with (1) WJ Quantitative Reasoning, (2) D-KEFS Inhibition and (3) an interaction term (Quantitative Reasoning x Inhibition) as the predictors and the AnimaLogica posttest residual as an outcome variable turned out to model the data significantly better than use of the mean of the outcome variable alone; *F*(3, 206) = 11.0, *p* = .000. The predictors were able to predict 14% of the variance in the outcome variable.

As can be seen in Table 3, only one of the two main effects, that is, the WJ Quantitative Reasoning, was significant, being of a moderate size (β = .34). The D-KEFS Inhibition did not reach significance, having a fairly trivial effect size (β = -.12). The interaction effect turned out to be virtually zero. It can be concluded that the latter two variables (D-KEFS Inhibition and especially the interaction term Inhibition*Quant_Reasoning) possessed almost no incremental predictive power above and beyond WJ Quantitative Reasoning.

Table 3
Regression model coefficients

	Unstandardized		Standardized	*t*	*p*
	SE	*Beta*			
(Constant)	,002	,065		0,03	.98
WJ Quantitative Reasoning	,092	,017	.34	5,28	.00
D-KEFS Inhibition	-,004	,002	-.12	-1,77	.08
Inhibition*Quant_Reasoning	,000	,001	.02	0,26	.79

Note. Outcome Variable: AnimaLogica Post Residual. *B* = regression coefficient, *SE* = standard error, *t* = t value, *p* = significance.

Discussion

In the present study, we aimed to answer questions related to the interaction effect, that is, we tried to explain the relationship between gf (independent variable) and LP (dependent variable) by including a third explanatory variable: attentional control (AC). AC served as the moderator variable, which was supposed to clarify the nature of the relationship between the defined predictor and outcome variables (MacKinnon, 2008). The aim of the study was to examine whether attentional control can moderate the expected positive effect of fluid intelligence on learning potential.

The absence of the interaction effect cannot be adequately explained by a lack of statistical power. The virtually zero magnitude of the interaction term is straightforward evidence supporting the notion that the relationship between learning potential (AnimaLogica Post Residual) and fluid intelligence (WJ Quantitative Reasoning) is invariant regarding the level of attentional control (Inhibition*Quant_Reasoning). To disentangle the reasons behind the lack of an interaction effect (something that would normally be predicted by information processing theories), one needs to consider the specifics of executive functioning in the child population. In contrast to the adult population, where executive functioning has been shown to form a set of broadly distinct functions (Miyake et al., 2000), executive functioning in the child population is much more unitary in nature.

Until approximately 9 years of age, executive functions form a unitary construct (Brydges et al., 2012; Wiebe et al., 2011). Above that age, a gradual differentiation in executive functioning can be observed (Lehto et al., 2003; Ropovik, 2014) similar to that found in Spearman's law of diminishing returns (Spearman, 1904), where rising general ability (g) leads to the growth of specialized abilities. At the age of about nine and a half, several distinct executive functions can be identified, including working memory and attentional control. Although separate, they are still strongly associated within a structure of hierarchical relationships.

In the present study there was a non-significant bivariate relationship between attentional control and learning potential. Regardless of whether this finding was produced by measurement issues (attenuation of correlation by error variance) or a real absence of effect, the possible effect of attentional control on learning potential might be fully mediated by some higher order function like working memory, for instance, as previous research has shown (Ropovik, 2014).

At the same time, there are various views on the theoretical relationship between working memory and fluid intelligence. One of them, relevant to our findings, is that these two constructs are so highly correlated that they can be considered to have isomorphic properties (Colom et al., 2004; Jensen, 1998; Stauffer, Ree, & Carretta, 1996). In fact, working memory and fluid intelligence are known to be almost undistinguishable in children and very closely tied even at the onset of adulthood (Friedman et al., 2006; Brydges et al., 2012). Research has linked children's performance on fluid reasoning tasks, such as figural matrices, to their memory span and working memory capacity (for instance, Ackerman, Beier, & Boyle, 2005; Hornung et al., 2011; Kail, 2007; Tillman, Nyberg, & Bohlin, 2008). Stevenson (2012) found that a combination of age and working memory capacity was the best predictor of analogical reasoning pretest scores (that is, a measure of fluid intelligence). Lee et al (2009) also confirmed that working memory is a constituent component of (fluid) intelligence in their findings. Similarly, Mackey et al. (2011) found in their study that training fluid reasoning may improve working memory. Several studies have even pointed to a direct link between fluid intelligence and attentional control, measured by the Stroop test (for instance, Chuderski, Taraday, Nęcka, & Smoleń, 2012).

With regards to the above-mentioned studies, the same pattern of hierarchical relationship between attentional control and learning potential might thus obscure possible interaction between attentional control and fluid intelligence with respect to learning potential. Here, the invariance of the relationship between fluid intelligence and learning potential given various levels of attentional control may well be explained by the possibility that fluid intelligence already conveys the entire true effect of attentional control on learning potential at the age in question. If true, such a full mediation effect logically rules out any interaction.

In considering the implications for cognitive education, we might ask whether it all means that attentional control is inconsequential? The answer is probably not. Overall, a large body of evidence suggests that attentional control, and especially the inhibitory aspect, underpins higher cognition at a later age (see Anderson, Jacobs, & Anderson, 2008). Provided that one considers the inherent unitary yet dynamic character of children's cognition, it may be the case that such an indirect effect, as was hypothesized, will manifest itself once cognition becomes more diversified later on during development.

References

Ackerman, P., Beier, M., & Boyle, M. (2005). Working memory and intelligence: The same or different constructs? *Psychological Bulletin, 131*(1), 30-60.

Aiken, L. S., & West, S. G. (1991). *Multiple regression: Testing and interpreting interactions*. Newbury Park: Sage.

Alloway, T. P. (2009). Cognitive training: Improvements in academic attainments. *Professional Association for Teachers of Students with Specific Learning Difficulties,* 22, 57-61.

Alloway, T. P. (2010). Working memory and executive function profiles of students with borderline intellectual functioning. *Journal of Intellectual Disability Research, 54*(5), 448-456.

Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology, 106*(1), 20-29.

Anderson, V., Jacobs, R., & Anderson, P. J. (Eds.). (2008). *Executive functions and the frontal lobes: A lifespan perspective*. NY: Psychology Press.

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4*(11), 417–423.

Baddeley, A. D., & Hitch, G. (1974). Working memory. In G.H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 8, pp. 47–89). New York: Academic Press.

Banich, M. T., Milham, M. P., Atchley, R., Cohen, N. J., Webb, A., & Wszalek, T. (2000). fMRI studies of Stroop tasks reveal unique roles of anterior and posterior brain systems in attentional selection. *Journal of Cognitive Neuroscience, 12*(6), 988-1000.

Blair, C. (2006). How similar are fluid cognition and general intelligence? A developmental neuroscience perspective on fluid cognition as an aspect of human cognitive ability. *Behavioral and Brain Sciences, 29*(2), 109-160.

Brydges, C. R., Reid, C. L., Fox, A. M., & Anderson, M. (2012). A unitary executive function predicts intelligence in children. *Intelligence,* 40, 458–469.

Budoff, M. (1987). The validity of learning potential assessment. In: C. S. Lidz (Ed.), *Dynamic assessment: An interactional approach to evaluating learning potential* (pp. 53-81). New York, NY: Guilford Press.

Carlson, J. S., & Wiedl, K. H. (1979). Toward a differential testing approach: Testing--the-limits employing the Raven matrices. *Intelligence, 3*(4), 323-344.

Carter, C. S., Mintun, M., Cohen, J. D. (1995). Interference and facilitation effects during selective attention: An (H2O)-O-15 PET study of Stroop task performance. *Neuroimage, 2*(4), 264-272.

Cattell, R. B. (1971). *Abilities: Their structure, growth, and action.* Boston: Houghton Mifflin.

Chuderski, A. (2014). Which working memory components predict fluid intelligence. *Psychology, 5*(5), 328-339.

Chuderski, A., Taraday, M., Nęcka, E., & Smoleń, T. (2012). Storage capacity explains fluid intelligence while executive control does not. *Intelligence, 40*(3), 278-295.

Colom, R., Rebollo, I., Palacios, A., Juan-Espinosa, & M. Kyllonen, P. (2004). Working memory is (almost) perfectly predicted by *g. Intelligence, 32*(2004), 277-296.

Conway, A. R. A., Cowan, N., Bunting, M. F., Therriault, D. J., & Minkoff, S. R. (2002). A latent variable analysis of working memory capacity, short-term memory capacity, processing speed, and general fluid intelligence. *Intelligence, 30*(2002), 163-183.

Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *Delis-Kaplan executive function system (D-KEFS).* San Antonio, TX: The Psychological Corporation.

Džuka, J., & Kovalčíková, I. (2008). Dynamické testovanie latentných učebných schopností [Dynamic testing of latent learning abilities]. *Československá Psychologie, 52*(4), 366-377.

Elliott, J., Grigorenko, E. L., & Resing, W. C. M. (2010). Dynamic assessment: The need for a dynamic approach. In E. Baker, B. McGraw, & P. Peterson (Eds.), *International encyclopedia of education* (3rd ed.). Oxford, United Kingdom: Elsevier.

Elliot, J. & Lauchlan, F. (1997). Assessing potential: The search for the philosopher's stone? *Educational and Child Psychology, 14*(4), 6-16.

Engle, R. W., & Kane, M. J. (2004). Executive attention, working memory capacity, and a two-factor theory of cognitive control. In B. Ross (Ed.), *The Psychology of Learning and Motivation* (pp. 145-199). New York, NJ: Elsevier.

Fabio, R. A. (2005). Dynamic assessment of intelligence is a better reply to adaptive behaviour and cognitive plasticity. *The Journal of General Psychology, 132*(1)*,* 41-64.

Ferrer, E., McArdle, J. J., Shawitz, B. A., Holahan, J. N., Marchione, K., & Shawitz, S. E. (2007). Longitudinal models of developmental dynamics between reading and cognition from childhood to adolescence. *Developmental Psychology, 43*(6), 1460-1473.

Feuerstein, R., Rand, Y., & Hoffman, M. (1979). *The dynamic assessment of retarded performers: The learning potential assessment device (LPAD).* Baltimore, MD: University Park Press.

Feuerstein, R., Rand, Y., Hoffman, M. B., & Miller, R. (1980). *Instrumental enrichment: An intervention program for cognitive modifiability.* Baltimore, MD: University Park Press.

Fiszdon, J. M., McClough, J. F., Silverstein, S. M., Bell, M. D., Jaramillo, J. R., & Smith, T. E. (2006). Learning potential as a predictor of readiness for psychosocial rehabilitation in schizophrenia. *Psychiatry Research, 143*(2-3), 159-166.

Freund, P. A., & Holling, H. (2011). Retest effects in matrix test performance: Differential impact of predictors at different hierarchy levels in an educational setting. *Learning and Individual Differences, 21*(5), 597-601.

Friedman, N. P., Miyake, A., Corley, R. P., Young, S. E., Defries, J. C., & Hewitt, J. K. (2006). Not all executive functions are related to intelligence. *Psychological Science, 17*(2), 172–179.

Haywood, H. C. (1997). Interactive assessment. In R. Taylor (Ed.), *Assessment of persons with mental retardation* (pp. 103–129). San Diego: Singular Publishing

Haywood, H. C., & Lidz, C. S. (2007). *Dynamic assessment in practice: Clinical and educational applications.* Cambridge, NY: Cambridge University Press.

Hornung, C., Brunner, M., Reuter, R. A. P., & Martin, R. (2011). Children's working memory: Its structure and relationship to fluid intelligence. *Intelligence, 39(4),* 210–22.

Hotulainen, R., Thuneberg, H., Hautamäki, J., & Vainikainen, M-P. (2014). Measured attention in prolonged over-learned response tasks and its correlation to high level scientific reasoning and school achievement. *Psychological Test and Assessment Modeling, 56*(3), 237-254.

Jeltova, I., Birney, D., Fredine, N., Jarvin, L., Sternberg, R. J., & Grigorenko, E. L. (2011). Making instruction and assessment responsive to diverse students' progress: Group-administered dynamic assessment in teaching mathematics. *Journal of Learning Disabilities, 44*(4), 381-395.

Jensen, A. R. (1998). *The g factor: The science of mental ability.* Westport, CN: Praeger.

Kail, R. V. (2007). Longitudinal evidence that increases in processing speed and working memory enhance children's reasoning. *Psychological Science, 18(4),* 312-313.

Kane, M. J., Hambrick, D. Z., Tuholski, S. W., Wilhelm, O., Payne, T. W., & Engle, R. W. (2004). The generality of working memory capacity: A latent variable approach to verbal and visuo-spatial memory span and reasoning. *Journal of Experimental Psychology: General, 133*(2), 189-217.

Kovalčíková, I. (2009). Dynamic testing and assessment of latent learning capacities. *Sosyal Bilimler Araştırmaları Dergisi,* 1, 47-53.

Kovalčíková, I. (Ed.). (2010). *Kognitívna stimulácia individuálnych edukačných potrieb* žiaka *zo sociálne znevýhodňujúceho prostredia* [Cognitive stimulation of individual educational needs of pupils from socially disadvantaging environments]. Prešov, Slovakia: Vydavateľstvo Prešovskej univerzity.

Lee, K., Pe, M. L., Ang, S. Y., & Stankov, L. (2009). Do measures of working memory predict academic proficiency better than measures of intelligence? *Psychology Science Quarterly, 51*(4), 403-419.

Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology, 21*(1), 59–80.

Lidz, C. (2000). The Application of Cognitive Functions Scale. In C. S. Lidz & J. G. Elliott (Eds.), *Dynamic Assessment: Prevailing models and applications*. Amsterdam: JAI/Elsevier Science.

MacDonald, A. W., Cohen, J. D., Stenger, V. A., & Carter, C. S. (2000). Dissociating the role of the dorsolateral prefrontal and anterior cingulate cortex in cognitive control. *Science, 288*(5472), 1835-1838.

Mackey, A. P., Hill, S. S., Stone, S. I., & Bunge, S. A. (2011). Dissociable effects of reasoning and speed training in children. *Developmental Science, 14*(3), 582-590.

MacKinnon, D. P. (2008). *Introduction to Statistical Mediation Analysis*. New York: Erlbaum.

McCandliss, B., Beck, I. L., Sandak, R., & Perfetti, C. (2003). Focusing attention on decoding for children with poor reading skills: Design and preliminary tests of the word building intervention. *Scientific Studies of Reading, 7*(1), 75-104.

Milham, M. P., Erickson, K. I., Banich, M. T., Kramer, A. F., Webb, A., Wszalek, T., & Cohen, N. J. (2002). Attentional control in the aging brain: Insights from an fMRI study of the Stroop task. *Brain and Cognition, 49*(3), 277-296.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “Frontal Lobe” tasks: A latent variable analysis. *Cognitive Psychology, 41*(1), 49–100.

Posner, M. I., & Dehaene, S. (1994). Attentional networks. *Trends in Neuroscience, 17*(2), 75-79.

Primi, R., Ferrão, M. E., & Almeida, L. S. (2010). Fluid intelligence as a predictor of learning: A longitudinal multilevel approach applied to math. *Learning and Individual Differences, 20*(5), 446–451.

Resing, W. C. M. (2013). Dynamic testing and individualized instruction: Helpful in cognitive education? *Journal of Cognitive Education and Psychology, 12*(1), 81-95.

Resing, W. C. M., Stevenson, C., & Bosma, T. (2012). Dynamic testing: Measuring inductive reasoning in children with developmental disabilities and mild cognitive impairments. *Journal of Cognitive Education and Psychology, 11*(2), 159-178.

Ropovik, I. (2014). Do executive functions predict the ability to learn problem-solving principles? *Intelligence,* 44, 64-74.

Schweizer, K. (2010). The relationship of attention and intelligence. In A. Gruszka, G. Matthiews, & B. Szymura (Eds.), *Handbook of individual differences in cognition: Attention, memory, and executive control* (pp. 247-262). New York: Springer.

Sergi, M. J., Kern, R. S., Mintz, J., & Green, M. F. (2005). Learning potential and the prediction of work skill acquisition in schizophrenia. *Schizophrenia Bulletin, 31*(1), 67-72.

Spearman, C. (1904). “General Intelligence,” objectively determined and measured. *The American Journal of Psychology, 15*(2), 201-292.

Stanovich, K. E., Cunningham, A. E., & Freeman, D. (1984). Intelligence, cognitive skills and early reading progress. *Reading Research Quarterly,* 14, 278-303.

Stauffer, J. M., Ree, M. J., & Caretta, T. R. (1996). Cognitive-components tests are not much more than *g*: An extension of Kyllonen's analysis. *Journal of General Psychology,* 123, 193-205.

Sternberg, R. J., & Grigorenko, E. L. (2002). *Dynamic testing: The nature and measurement of learning potential.* New York, NY: Cambridge University Press.

Sternberg, R. J., Grigorenko, E. L., Birney, D. P., Fredine, N., Jarvin, L., & Jeltova, I. (2007). Dynamic instruction for and assessment of developing expertise in four ethnic groups. In E. J. Gubbins (Ed.), *Research Monograph of the National Research Center on the Gifted and Talented.* University of Connecticut.

Stevenson C. E. (2012). *Puzzling with potential. Dynamic testing of analogical reasoning in children* (Doctoral dissertation, Leiden University). Amsterdam, the Netherlands: Ipskamp Drukkerij.

Stevenson, C. E., Hickendorff, M., Resing, W. C. M., Heiser, W., & de Boeck, P. (2013). Explanatory item response modeling of children's change on a dynamic test of analogical reasoning. *Intelligence, 41*(3)*,* 157-168.

Swanson, H. L. & Howard, C. B. (2005). Children with reading disabilities: Does dynamic assessment help in the classification? *Learning Disability Quarterly, 28*(1), 17-34.

Swanson, H. L., & Lussier, C. M. (2001). A selective synthesis of the experimental literature on dynamic assessment. *Review of Educational Research, 71*(2), 321-363.

Taub, G., Floyd, R. G., Keith, T. Z., & McGrew, K. S. (2008). Effects of general and broad cognitive abilities on mathematics. *School Psychology Quarterly*, *23*(2*),* 187-198.

Taylor, T. R. (1992). Beyond competence: Measuring potential in a cross-cultural situation fairly. Potential in psychometrics. In *Congress on psychometrics for psychologists*. Megawatt Park, Sandton: Eskom and the Society of Industrial Psychology of South Africa.

Tillman, C. M., Nyberg, L., & Bohlin, G. (2008). Working memory components and intelligence in children. *Intelligence, 36*(5), 394-402.

Tzuriel, D. (2000). Dynamic assessment of young children: Educational and intervention perspectives. *Educational Psychology Review, 12*(4), 385-435.

Unsworth, N., & Engle, R. W. (2007). The nature of individual differences in working memory capacity: Active maintenance in primary memory and controlled search from secondary memory. *Psychological Review, 114*(1), 104-132.

Unsworth, N., & Spillers, G. J. (2010). Working memory capacity: Attention, memory, or both? A direct test of the Dual-Component Model. *Journal of Memory and Language,* 62, 392-406.

Vygotsky, L. S. (1962). *Thought and language.* Cambridge MA: MIT Press.

West, R., Alain, C. (2000). Effects of task context and fluctuations of attention on neural activity supporting performance of the Stroop task. *Brain Research, 873*(1), 102-111.

Wiebe, S. A., Sheffield, T., Nelson, J. M., Clark, C. A., Chevalier, N., & Espy, K. A. (2011). The structure of executive function in 3-year-olds. *Journal of Experimental Child Psychology, 108*(3), 436–452.

Wiedl, K. H. (1999). Cognitive modifiability as a measure of readiness for rehabilitation. *Psychiatric Services, 50*(11), 1411-1413.

Wiedl, K. H. (2003). Dynamic testing: A comprehensive model and current fields of application. *Journal of Cognitive Education and Psychology, 3*(2), 93-119.

Wiedl, K. H., Schottke, H. H., & Calero-Garcia, D. (2001). Dynamic assessment of cognitive rehabilitation potential in schizophrenic persons and in elderly persons with and without dementia. *European Journal of Psychological Assessment*, *17*(2), 112-117.

Wiedl, K. H., & Wienobst, J. (1999). Interindividual differences in cognitive remediation research with schizophrenic patients: Indicators of rehabilitation potential? *International Journal of Rehabilitation Research, 22*(1)*,* 55-59.

Authors:

Marta Filickova, Ph.D.
University of Presov
Faculty of Education
Department of Preschool and Elementary Education and Psychology
17. Novembra 15
Presov
080 01
Slovakia
Email: marta.filickova@unipo.sk

Ivan Ropovik, Ph.D.
University of Presov
Faculty of Education
Department of Preschool and Elementary Education and Psychology
17. Novembra 15
Presov
080 01
Slovakia
Email: ivan.ropovik@unipo.sk

Monika Bobakova, Ph.D.
University of Presov
Faculty of Education
Department of Preschool and Elementary Education and Psychology
17. Novembra 15
Presov
080 01
Slovakia
Email: monika.bobakova@unipo.sk

Iveta Kovalčíková, Associate Professor
University of Presov
Faculty of Education
Department of Preschool and Elementary Education and Psychology
17. Novembra 15
Presov
080 01
Slovakia
Email: iveta.kovalcikova@unipo.sk