

## Diagnostic tools for assessment of cognitive functioning in children and youth – the implementation project

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### ABSTRACT

#### **Purpose**

The aim of this article is to present the application value of a diagnostic toolkit for assessment of cognitive functions based on a proprietary Multidimensional Model of Cognitive Functioning which combines executive functions with the field of perception, language, and communication.

#### **Theses**

The developed tools assess the level of executive functions (attention control, working memory, cognitive flexibility, and reasoning), the speed of perceptual processes, as well as linguistic functions in terms of speech- and writing-based communication.

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## Conclusions

All tasks have been prepared in a computer-based version. The innovativeness of the proposed battery of tests stems from the fact that the adopted model creates a coherent theoretical framework for the entire spectrum of functions describing the effectiveness of cognitive processing in people of different ages and varying educational needs. In the context of the tools available in psychological and pedagogical counselling centres, this technically advanced tool will be the first test available on the Polish market covering such a broad spectrum of cognitive functions. The tool has been designed to enable the diagnosis of diverse groups of people with special educational needs – from gifted children, through people with intellectual disabilities, visual and hearing impairments, neurodevelopmental disorders (e.g. autism), and language disorders and dyslexia, to migrant children. This broad scope of application was made possible by implementing the WCAG 2.1 and universal design principles.

**Keywords:** measurement tools, cognitive functions, children and youth.

## INTRODUCTION

### Main goals and significance of the implementation project

Since 2018, the Educational Research Institute (project leader) and the SWPS University of Social Sciences and Humanities (project partner) have been cooperating on the project titled “The development and dissemination of diagnostic tools for the cognitive assessment of children and youth”. The project is co-financed by the European Union through the European Social Fund and its end is planned for 2022. Its aim is to develop, implement and popularise a set of tools (in the form of computer- and paper-based tests) for the assessment of cognitive functioning of children and youth aged between 3 months and 25 years (270 degree assessment). The developed tests, testing handbooks and post-diagnostic materials will be delivered to all psychological and pedagogical counselling centres in Poland in the second half of 2022.

The project will result in the development and dissemination of one coherent set of innovative diagnostic tools for assessing the cognitive development of children and youth aged between 3 months and 25 years. The set will include a battery of computer-based cognitive tests, observation scales for assessment of cognitive development to be used by parents and teachers, and a set of post-diagnostic materials facilitating efforts aimed at stimulation of children’s cognitive development. Taking the form of a modern computer application containing tests and post-diagnostic materials for specialists and teachers alike, the tools are economical and easy to use, as well as open to further expansion and updates. The goal of the project is to develop a set of tools for the specialist diagnosis of cognitive functioning of children and youth. The tools have been developed on the basis of a proprietary and innovative theoretical concept covering both executive functions (attentional control, cognitive flexibility, working memory, and reasoning) and the field of perception, language, and communication. The diagnostic toolkit includes a battery of

tests that measure cognitive functions, including executive functions, perception, and language functions. The assessment consists in children and youth doing visually attractive tests within an application, which ensures full standardisation of the assessment and accelerates the diagnosis process through automatic calculation and creation of result profiles. The battery of tests offered through a computer application, known as **KAPPa** (from Polish “Kompleksowa Analiza Procesów Poznawczych – aplikacja” which translates into “Comprehensive Assessment of Cognitive Processes – an application”), makes it not only easy to select and conduct appropriate tests, but also to make the functional diagnosis.

The tests will be standardised on the basis of a nationwide sample of children and youth aged between 3 months and 25 years, with forms of tests and tasks adapted to their respective ages. The developed diagnostic tools will also be used to perform the assessment of students with disabilities and special educational needs (SEN), which will be described in more detail in the second part of the article. Cognitive function profiles will be developed for all groups. Such approach will make it possible to increase the effectiveness of diagnosis, education, and support efforts.

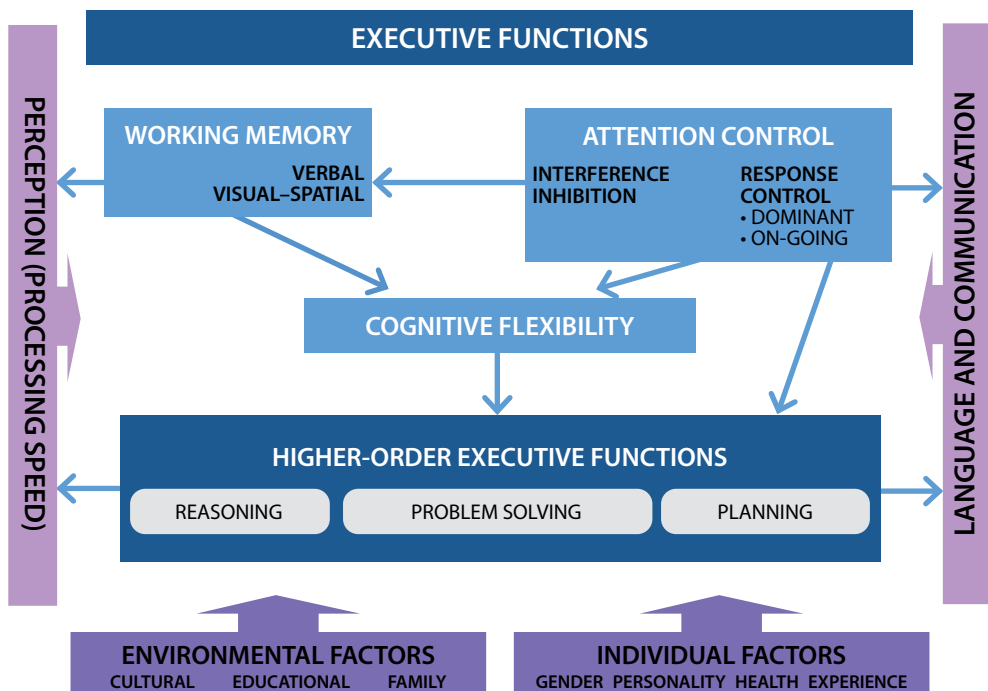
## IMPLEMENTATION PROJECT: COMPREHENSIVE ASSESSMENT OF COGNITIVE PROCESSES (KAPP)

### **The theoretical basis of the implementation project**

The substantive concept of a diagnostic toolkit for measuring cognitive functions is based on the proprietary Multidimensional Model of Cognitive Functioning (MMCF) whose structure combines executive functions (Diamond, 2013) with the field of perception, language, and communication (see Fig. 1, p. 12). The MMCF was created on the basis of the model of executive functions (Diamond, 2013), the structural model of the language system (Kurcz, 2000; Milewski, 1965), and the psycholinguistic model of the phonological subsystem (Krasowicz-Kupis et al., 2015), as well as the results of research on the importance of the model’s psychological variables for the broadly understood educational success, both in the general population of students and in groups of students with special educational needs (Elliot & Grigorenko, 2014; Peterson & Pennington, 2012).

Executive functions (EFs) are essential for proper mental and physical development in various spheres of life (Diamond, 2013). The term executive functions covers the cognitive and neuropsychological mechanisms responsible for managing and coordinating multiple aspects of perception, cognition, emotion, and action (Gioia et al., 1996; McCloskey & Perkins, 2013; Stuss & Alexander, 2000). Executive functions can also be defined as mental processes related to the regulatory control over attention, thoughts, and purposeful behaviour (Engle et al., 2005), which are necessary to inhibit automatic responses.

Contemporary educational psychology theories emphasise that educational progress is the result of a complex interaction of intra- and interpersonal factors (Armitage, 2008; Corno & Anderman, 2016). Hence, education studies increasingly



**Fig. 1.** The proprietary Multidimensional Model of Cognitive Functioning (MMCF), based on the concept of executive functions combined with perceptual speed and language and communication, as the basis for the functional diagnosis

take into account both internal and external variables influencing the learning process (e.g. Greenwood et al., 1990; Kelly & Perkins, 2012). Internal factors determine students' developmental abilities, while external factors can help them develop their potential. Research indicates that difficulties in acquiring complex school knowledge can be attributed to deficits in cognitive control (executive functions) rather than a lack of intellectual abilities (Bull & Scerif, 2001; Welsh & Pennington, 1988). The measurement of executive functions was included the proposed theoretical concept, as numerous studies indicate that EFs are important for many aspects of human life, especially those related to education, i.e.:

- school readiness – EFs are better predictors of school readiness than IQ or early signs of literacy and numeracy skills (Blair & Razza, 2007; Morrison et al., 2010);
- school success – EFs are predictive for the achievements in mathematics and reading comprehension reached in the course of school (Borella et al., 2010; Duncan et al., 2007; Gathercole et al., 2004) and pre-school education (Sędek et al., 2016);
- professional success – weakened EFs result in a lower productivity and difficulties in finding and keeping a job (Bailey, 2007);

- quality of life – people with higher-rated EFs enjoy a higher quality of life (Brown & Landgraf, 2010; Davis, et al., 2010).

Consequently, the theoretical model on the basis of which the diagnostic tool for the assessment of cognitive functions will be constructed, i.e. the proprietary Multidimensional Model of Cognitive Functioning (MMCF), covers executive functions in conjunction with perceptual processes (especially processing speed) and the field of language and communication. The model will serve as the basis for the functional diagnosis and the construction of a diagnostic tool (see Fig. 1, p. 100). The MMCF is consistent with the biopsychosocial model of health developed to facilitate implementation of the rights of children and youth arising from the provisions of the UN Convention on the Rights of Persons with Disabilities, which was ratified by Poland in 2012. This approach fosters inclusion, as opposed to exclusion, of students with special educational needs (SEN) and allows for improving the effectiveness of education and support offered to such students to help them develop their individual potential and prepare them for being self-reliant in their adult lives.

Executive functions are a broad concept that includes many traditionally diagnosed cognitive functions, such as perception, attention, memory, and reasoning. On the other hand, perception (processing speed) and linguistic functions, and consequently also communication, remain in an on-going mutually impactful relationship with those functions. The proposed set of tasks for measuring executive functions and perception is presented in Table 1, while the set of tasks for testing language functions and communication skills is presented in Table 2 (p. 102).

**Table 1**

**A set of tasks measuring executive functions and perception**

<b>Executive functions and perception</b>	
<b>Sub-area</b>	<b>Task</b>
<b>Basic executive functions</b>	
	Anti-saccade task
Attention control processes	Stroop task
	Go/no-go task
Working memory	Counting span task
	Operation span task
Cognitive flexibility	Switching task
<b>Complex executive functions</b>	
	“Linear Order” task
Reasoning (problem-solving, planning)	“Analogies” task
	“Proverbs” task
	“Tower” task

continuance of Table 1

<b>Executive functions and perception</b>	
<b>Sub-area</b>	<b>Task</b>
	<b>Perception</b>
	Comparison task
Perceptual speed (processing speed)	Search task
	Perceptual speed task

**Table 2**

**A set of tasks that measure linguistic functions**

<b>Area</b>	<b>Sub-area</b>	<b>Tasks</b>
<b>Speech</b>	Phonology	Syllable analysis – words and pseudo-words
		Phonemic analysis – words and pseudo-words
		Phoneme deletion
	Grammar	Repeating sentences
		(Understanding instructions)
	Semantics	Understanding instructions
		(Repeating sentences)
		(Proverbs)
	Pragmatics	Proverbs
		(Reading comprehension)
<b>Reading</b>	Knowledge of letters	Letter recognition
		Naming letters
	Reading – decoding	Decoding – words
		Decoding – pseudo-words
	Reading – understanding	Reading comprehension
	<b>Writing</b>	Writing

All tasks for the assessment of executive and linguistic functions will be prepared in the form of a computer-based application (KAPPA). They will be created in a homogeneous and user-friendly programming environment. The use of this type of environment will allow for the automatic preparation of a report that determines the level of functioning of the assessed functions, including working memory, attention control, and reasoning, as well as a profile analysis of specific

functions relating to the International Classification of Functioning, Disability and Health (ICF).

The innovativeness of the proposed battery of tests stems from the fact that the proposed model creates a coherent theoretical framework for the entire spectrum of functions describing the effectiveness of cognitive processing in people of different ages and varying educational needs. This technically advanced tool will be the first test available on the Polish market that covers such a broad spectrum of cognitive functions, especially in the context of the tools available in psychological and pedagogical counselling centres.

### **Adjustments for SEN groups**

The KAPPA application is intended to be used for the assessment of certain groups of children and youth with special educational needs, including children and youth with:

- mild intellectual disabilities,
- vision impairments,
- hearing impairments,
- autism spectrum disorders,
- language communication disorders (including language disorders),
- specific learning disorders, primarily dyslexia,
- ADHD,

as well as bilingual children, children raised in different cultures, children returning from abroad, and highly gifted children.

For the above reason, the KAPPs battery has been especially designed to allow for diagnosing executive, perceptual, and communicative functions in a comparable manner in groups with various types of educational needs. To achieve this goal, the development of the tests was based on the principles of universal design and the Web Content Accessibility Guidelines (WCAG). They were implemented in the maximum possible scope which still allowed for maintaining the construct validity of the tool and objectivity related to comparable, if not identical, conditions for conducting assessments.

### **Universal design and WCAG in the context of the KAPPA design**

The Universal Design (UD) is consistent with the biopsychosocial model of disability, which constitutes a set of guidelines for educational activities related to offering psychological and pedagogical support, including the diagnostic process. Initially, this idea concerned only the availability of physical space for all potential users (Mace, 1985), but later it was expanded to cover many areas of human activity, especially in the context of inclusive education (Hall et al., 2012; Rose et al., 2005; Spencer, 2011). In the field of psychological assessments, the UD refers to the universal design of diagnostic tools (Universally Designed Assessments, or UDA) (Thompson et al., 2002). Numerous studies confirm that the use

of UDA-compliant tests elicits better results when compared to the traditional versions of tests not only from students from SEN groups, but all students in general (Acrey et al., 2003; Dolan, 2005; Knopik, 2008). The so-designed diagnostic tools allow the assessed people to react to the test tasks in whatever manner is available to them, and make it possible for the diagnostician to recognise their real needs and abilities. The universal design of test materials ensures that all potential respondents have equal access to the content layer of tasks, which provides them with equal opportunities to demonstrate their real competences (Domagała-Zyśk et al., 2017; Ketterlin-Geller, 2005). Features of UDA-compliant diagnostic tools which may be relevant for this context include their accessibility, flexibility, intuitiveness, and tolerance for error (Connell et al., 1997).

Computer-based tool design seems to be particularly useful, but such tests must meet the conditions set for psychological tests as standardised tools in computer-based testing (International Test Commission, 2005). In addition, they must meet the digital accessibility requirements specified in WCAG 2.1. The design of KAPPA took the above-mentioned principles into consideration.

### **WCAG and the design of KAPPA**

The WCAG (Web Content Accessibility Guidelines) provide instructions on how to ensure accessibility of web content to the widest possible audience, including people with various operational limitations. They provide advice on designing websites and applications in a manner accessible to people with disabilities, e.g. visual or hearing impairments, and reduced mobility, but also with intellectual disabilities or cognitive disorders. The WCAG include a set of recommendations that should be implemented to ensure that web content and applications are accessible to as wide as possible group of users, including people with disabilities. If these recommendations are met, the materials are suitable for people with disabilities, and will be clear for their recipients, including digitally excluded individuals.

The most up-to-date version of the guidelines, WCAG 2.1, which was used in the design and development of the KAPPA application, is based on 4 principles: visibility, functionality, comprehensibility and reliability (compatibility). Implementation of these guidelines ensures that the design process takes into consideration different users who cannot see the screen but still want to access its content, ones who can use a keyboard, but not a mouse, or ones that need to zoom in or change the colours to better see the content, etc.

### **Adaptations of KAPPA to the assessment of children and youth with special educational needs**

The KAPPA battery, available as a computer application, uses numerous design and operational elements to allow for optimal assessment of children from various groups with special educational needs, including both gifted children and



children with disabilities or neurodevelopmental disorders. Two types of adjustments were introduced into the KAPPA design, in line with the above-presented WCAG and UDA principles. First of all, the general ones, which were included in the basic version of the test and applied to all assessed groups, including the general population, and, s, the detailed adjustments which are aimed at and applied only to specific SEN groups, taking into account their accessibility needs.

The general adjustments included in the KAPPA app as a result of implementing the UDA and WCAG principles, concern the following areas:

- formulation of the instructions,
- training tasks,
- possibility of repeating instructions and training attempts,
- adjusted font characteristics,
- clear structure of the materials,
- uniform visual features for the entire application and its specific stages,
- functional profiles and possibly additional standards for SEN groups.

On the other hand, detailed adjustments taking into account the same principles and the specificity of individual SEN groups, include:

- elimination of tasks which are inaccessible for a given SEN group – e.g. typically, visual-based tasks for blind recipients,
- additional tasks for selected SEN groups – e.g. for highly gifted individuals, or audio versions of tests for the visually impaired, and syllable analysis tasks for people with mild intellectual disability,
- an option of taking the tests under modified conditions (e.g. without the time limits, or with disabled read-out instructions and/or items and with the examiner reading them out loud in person instead).

Applying the UD principles to the content or interpretation layer of the test scales (intraindividual variability, general and group-specific norms) makes it possible to also obtain information about individual strengths of SEN children, which is especially useful in designing interventions to be implemented in school, e.g. developing activities for the Individual Educational and Therapeutic Programmes (Elder & Kuja, 2018; Weishar, 2010), developing strategies in the field of psychological counselling (Magyar-Moe et al., 2015), and supporting activities aimed at stimulating the afore-mentioned strengths (Cosden et al., 2006). A tool designed in accordance with the UD principles is sensitive to such changes, which allows for formulation of conclusions about the development progress of the assessed individuals in a longitudinal perspective.

Diagnostic conclusions obtained on the basis of an assessment conducted with such a tool provide the basis for a much more individualised therapeutic process. This, in turn, makes it possible to translate diagnostic descriptions into specific activities which can be carried out at school.

## Research description

The process of designing KAPPA followed the standard stages of designing tools of this type (cf. Hornowska, 2014). It began with establishment of the theoretical

assumptions and development of the initial item pool for individual tests, and, afterwards, moved on to the pre-pilot and pilot studies. The aim of the conducted design and validation tests was to assess the reliability and accuracy of the measurements made with the help of the tool in question. Aside from the reliability analyses, the development team performed also related analyses of test items, assessing their difficulty levels and discriminating power. The analyses were performed with the help of both classical test theory and IRT. The conducted validity analysis was multifaceted. For example, in accordance with the multitrait-multimethod (MTMM) procedure, the correlation matrix was assessed in comparison with battery tests with a known level of reliability and validity. The study used the Intelligence and Development Scales (IDS-P) (Grob et al., 2015) and IDS-2 (Grob et al., 2018). Validation tests were also carried out in laboratory conditions with the help of the eye-tracking method. In total, 1,400 people were tested at this stage, including 360 individuals with special educational needs. Presentation of the results of these studies exceeds the scope of this article.

The current stage of the process focuses on the standardisation studies involving a general group and 9 groups of people with special educational needs and disabilities (dyslexia, ADHD, language communication disorders, students with above-average intellectual potential, students for whom Polish is a second language, people with mild intellectual disability, visual impairments, hearing impairments, or autism spectrum disorders). In total, 1,760 people from a nationwide representative general group and over 3,000 people with special educational needs will take part in this stage of development. Once the studies and tests are completed, their results will be used to develop standards for both the general group and selected clinical groups, which will allow for using the battery in question in psychological diagnosis.

### **Comparison between KAPPA and existing test batteries for assessment of cognitive functions**

There are several test batteries for assessment of cognitive functions which psychologists in Poland have at their disposal. They include:

- Intelligence and Development Scales (IDS) (three versions)
- Stanford–Binet Intelligence Scales. Fifth edition – SB5
- Wechsler Intelligence Scale for Children. Fifth Edition, i.e. WISC-V.
- Leiter-3, Leiter International Performance Scale.

Intelligence and Development Scales can serve as good examples of batteries – large-scale tools which are used in a broader diagnosis of children. Test batteries are used to conduct comprehensive assessments of abilities and competences, e.g. general, fluid and crystallised intelligence, as well as cognitive functions, psychomotor skills, socio-emotional competences, mathematical and language competences, and children and youth's achievement motivation. So far, three versions of IDS scales have been published in Poland. They are, respectively:

- Intelligence and Development Scales for Children Aged 5–10 (IDS),
- Intelligence and Development Scales for Pre-school-aged Children (IDS-P),

- Intelligence and Development Scales for Children and Youth (IDS-2) (Fecenec et al., 2015; Grob et al., 2018; Jaworowska et al., 2012).

The above-listed batteries are used to assess the general intellectual development in the form of general indicators, such as quotients of general intelligence, as well as fluid and crystallised intelligence. They also provide many additional complex and detailed indicators concerning cognitive functioning. They can be used to analyse many different cognitive and non-cognitive aspects, such as persistence and motivation. Newer batteries, such as WISC-V and IDS-2, include also tasks that allow for the assessment of selected executive functions. Most of them, with the exception of IDS-2, do not contain any specialised tests for the assessment of language communication, especially in terms of writing or selected language subsystems. Moreover, in all the batteries mentioned, the tests are carried out in a conventional manner. That is, children perform tasks using real physical materials, for example blocks, or various types of standardised paper illustrations. The psychologist provides instructions, measures the time, records the results manually and personally assesses the answers.

The features offered by KAPPA make it stand out among other batteries. First of all, KAPPA is not meant to assess the general intellectual development and does not use the IQ. It is designed to be used for the functional assessment which takes into account a number of detailed cognitive areas and sub-areas. What is more, the test is entirely computer-based, which allows for more precise measurement of certain aspects of the assessed functions, such as task execution time and response time. Additionally, the use of KAPPA makes the assessment more objective, because the assessment of the vast majority of tasks is performed automatically by a computer programme, and the instructions are fully standardised and read out loud by the programme. In terms of the assessed functions, KAPPA provides a unique mix of options, combining the afore-mentioned linguistic functions, including written communication, with very detailed measurements of executive functions relating to cognitive tasks of various difficulty levels – from basic to complex. It can therefore be said that the KAPPA battery constitutes a valuable supplement to the already existing psychological tools, as it allows for making the functional diagnosis, supporting the process of planning support activities.

## SUMMARY

Polish psychological and pedagogical counselling centres do not have many diagnostic tools that allow for a comprehensive assessment of a child's cognitive functioning, including their speech, reading and writing skills, as well their underlying cognitive abilities. The available tools are often intended only for a specific age group or for assessing specific, narrow areas of cognitive development. Moreover, they are usually not suitable for conducting assessment of children with special educational needs (children with various types of mental or physical disabilities or significant developmental difficulties, as well as gifted children).

The main goal of this project is to provide the counselling centres with modern (based on computer-administered tests) and reliable tools supporting a valid and comprehensive educational diagnosis of children, youth, and adults (in particular, in the case of some SEN groups, adults which remain in the educational system up to the age of 25).

Both basic and complex executive functions, as well as language and communication skills, are crucial for many aspects of people's functioning, especially for acquisition of knowledge and skills. Executive functions have a huge impact on proper mental and physical development, as they allow to control such processes as perception, attention, memory, planning, reasoning, and problem solving. They allow for effective regulation of human thoughts and emotions, as well as deliberate behaviour. Together with the language skills, they determine school readiness, and subsequent educational and professional successes, which affects people's overall quality of life.

A good diagnosis of the described areas of cognitive development, made in cooperation with caregivers, teachers and specialists, is an important step in equalising educational opportunities of children, supporting their development, and implementing support and preventive measures. Recognising individual abilities and needs of children makes it possible to understand their cognitive functioning, and thus improve their skills in specific weak areas in the course of education, using their individual strengths and abilities. What is more, such an approach helps to prevent difficulties in other spheres of human functioning, such as social activity or emotional functioning, which may arise as a consequence of developmental and educational difficulties.

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