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STRUCTURE AND CORRELATES OF INFORMATION PROCESSING SPEED

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INTRODUCTION

Relevance of the research

By means of evolved or learned psychological mechanisms all living beings constantly solve problems of varying complexity. The decisions that are being made must be adaptive, that is, increase survival of populations or species (Barrett, 2008). In case of escaping a threat or hunting prey, movement coordination, planning or spatial apprehension are useless if they are not swift enough. So the speed of cognitive task performance is undoubtedly essential for individual and species survival.

In 21st century, speed is still important for human cognitive efficiency. In cognitive psychology and neuropsychology this measure of psychic activity was referred to as psychic tempo, but is now referred to as *information processing speed* (IPS). A certain level of information processing speed is required in everyday tasks (Gross, Rebok, Unverzagt, Willis, & Brandt, 2011), and tasks requiring quick reactions, for example, driving a car (Edwards et. al., 2009). IPS is also important in professions associated with speed and efficiency demands, for example, pilots (Kennedy et. al., 2013), surgeons (Gettman et. al., 2003), military (Laurence & Matthews, 2012), athletes (Finch & Zelinski, 2005). Furthermore, IPS plays a crucial role in development across the lifespan from birth to old age. Results from existing research show that early psychomotor abilities (Piek, Dawson, Smith & Gasson, 2008), school achievement (Dodonova, & Dodonov, 2012), academic performance (Rohde & Thompson, 2007), work success (Lang, Kersting, Hulsheger, & Lang, 2010), and even usage of technology in old age (Czaja & Lee, 2007) are all related to IPS.

IPS is measured using reaction time, decision time or other cognitive tasks that virtually all test-takers would be able to solve correctly given enough time to work on them. Analyzing intercorrelations between different measures of IPS and relations between IPS measures and other cognitive domains are essential for understanding human cognitive structure and IPS role in it (Salthouse, 2000, Deary & Stough, 1996; Bors & Forrin, 1995; Carroll, 1993; Catts, Gillispie, Leonard, Kail, & Miller, 2002;

Helmbold, Troche, & Rammsayer, 2007). Furthermore, many researchers are analyzing different demographic, health and psychosocial correlates of different factors of IPS.

Actually one of the main reasons of interest in IPS is the fact that age-related decline in information processing speed is seen as the basic process of cognitive aging (Borella, Ghisletta, & de Ribaupierre, 2011; Kail & Salthouse, 1994; Lee et al., 2012; Salthouse, 1992; Salthouse, 1996). It has been shown that IPS decline might be a fundamental feature mediating cognitive decline in other domains. IPS performance grows rapidly up until early 20s and declines slowly later resembling an inverted letter U. Research analyzing these phenomena is very important due to decline in birth rate and rapid aging of the western world.

Life course prevalence of mental illness also increased due to rapid aging in western society. Mental illness is a serious public health issue. It is estimated that each year approximately 38 % of the EU population suffers from mental disorders (Wittchen et. al., 2011). Although for some time mental illness was not regarded a serious risk for public health as it is rarely a cause of death, now it is being widely accepted to cause considerable financial and disability burden, also various psychological and sociological problems (WHO, 2006, Wittchen et. al., 2011). Although, without a doubt, psychiatric disorders are etiologically and clinically extremely heterogeneous, virtually without exception they are related to IPS decline. This relationship is explained by biological changes in the organism during the process of aging and mental illness (Kochunov et. al., 2016). Biological and psychosocial aspects of mental illness are major areas of contemporary scientific interest. However, one of important and less analyzed aspects is IPS.

Although IPS has been called a “lower” cognitive function (Bott et. al., 2014, Grassi & Borella, 2013, Kaufman, DeYoung, Gray, Brown, & Mackintosh, 2009), contemporary research in cognitive psychology reveals the importance of IPS on individual differences in general intelligences (Anderson, 2015) and it has even been considered to be the main component of intelligences (Anderson, 2001). Furthermore, IPS cannot be dissociated form its complex relations with personality, health, or social and economic environment. This integration of biological, cognitive, social and psychological variables is crucial for understanding IPS correlates and its predictive model creation.

This research focuses on certain important theoretical and practical issues. First, indicating variables associated with IPS and creating biopsychosocial models of IPS is essential because current studies show that IPS is involved in various domains of human cognition and behavior. Second, IPS is one of the most important indicators of cognitive aging. Relevance of investigating this phenomenon is increased because of population aging in western societies (Llewellyn, Lang, Langa, & Huppert, 2008). Third, analyzing IPS in mental illness could contribute to understanding of mechanisms underlying individual differences in IPS. Fourth, research of structure and cognitive correlates of IPS is still developing and could contribute to cognitive models that integrate simple and complex IPS as separate cognitive abilities.

Scientific novelty

This work is novel in several ways. First, this work describes an integrated path model of relationships between age, mental illness and cognitive abilities at the center of which are simple and complex information processing speed constructs. Demographic, psychosocial and health variables, as well as age and mental illness are all described as a unitary system relating to human functioning. This model is closely linked to Salthouse (1996) theory of adult age differences in cognition and other cognitive models integrating IPS (Anderson, 2001, Anderson, 2003, Deluca, 2008), also models of active and passive cognitive reserve (Stern, 2003, Stern, 2009), and biopychosocial model (Smith, Fortin, Dwamena, & Frankel, 2013).

This work aims to identify demographic, health and psychosocial predictors of simple IPS and complex IPS. Importantly, this research shows that even psychosocial variables (i.e. subjective socioeconomic status, subjective social connectedness, neuroticism) are related not only to complex IPS but also to simple IPS. To our knowledge, this is one of the first reports of relationship between social connectedness, simple IPS and complex IPS. We suggest that this relationship might be explained in terms of evolutionary and neuropsychological mechanisms. Although these relationships are relatively weak further investigations are need. We think that many relationships identified in the final model deserve further investigation.

Second, this research analyzes correlates of simple IPS and complex IPS instead of a broader construct of general IPS. Though the idea that tests of cognitive speed measure more than one construct of abilities is common and sometimes applied in research, evidence for multidimensional structure are still lacking. Also, it is still not clear which multidimensional IPS model best fits the data. One of the hypothesis is that IPS can be understood in terms of stimulus modality. For example, IPS measures can be divided into two categories: verbal and nonverbal. However, this structural model is not well supported by contemporary data analysis. On the other hand, two recent studies show (Chiaravalloti, Christodoulou, Demaree, & DeLuca, 2003; Cepeda, Blackwell, & Munakata, 2013), that it's not modality that best explains relationships between speed measures, but complexity of the data by separating simple and complex IPS constructs. Thus, this research is to our knowledge one of the first which analyzes variables related to simple IPS and complex IPS.

Third, we expand Salthouse (1996) theory of adult age differences in cognition to mental disorder related cognitive decline. This means that mediational role of IPS is being investigated in the relationship between mental disorder and other cognitive domains. This investigation is based on an assumption that limited time and simultaneity mechanisms that explain age-cognition relationships might be important in mental disorder related cognitive decline. It is important to note that neurological mechanism that underlie cognitive aging and mental illness do not have to be identical in order for cognitive mechanisms to be similar. This research supports the hypotheses that IPS plays a mediating role in mental disorder and cognition relationship.

Fourth, cognitive measurements were performed using computerized neuropsychological battery which is a fourth novelty that can not only be used for research purposes but also for application in practice. Despite the criticism that computerized cognitive testing has received in the beginning of this kind of research, today many psychological assessment tools are used in this form. For example, WAIS, WAIS-R, and WAIS-III have been used in paper-pencil form for decades, but recently computerized version of WAIS-IV was developed. First of all, computerized test administration is beneficial in speeded tasks as it allows millisecond accurate timing. Furthermore, in computerized testing instructions can readily be presented in a much more standardized fashion and the experimenter can focus on monitoring significant deviations from normal procedures and ensuring proper comprehension of the task. Lastly, computerized testing not only improves validity and standardization of the procedure, but also it is useful in various practical settings with less requirements for test preparation and administration.

Fifth, we applied a few methodological novelties in this research: 1) we used structural equation modeling not only for determining the structure of IPS, but also for showing structural invariance in age groups and also mental illness. To our knowledge, this is one of the first researches to use analysis of invariance of simple IPS and complex IPS structure. 2) Composite scores (more than one task per construct) of cognitive measures were used in order to compare groups and determine relationships. This allowed construct validity and avoiding unintended task-specific relationships. 3) A groups of not hospitalized outpatients selected from a general sample was used. Most previous research used only in-patients with mental illness. This allowed controlling for effects of mental health settings. These and other methodological novelties were used in order to understand differences between simple IPS and complex IPS and also to determine possible advantages of this division.

Practical significance

A neuropsychological test battery has been created for the purpose of this study. It is based on free-license open software, so this neuropsychological battery can be implemented in further research. This battery allows measurement of simple IPS, complex IPS, also includes different memory tests and mental set-shifting task. Furthermore, eleven tasks in this research can be integrated in other batteries fitting the purpose of particular research or thesis (for example, Dovydaitytė (2016), Surkevičiūtė (2016), Žliobaitė (2016)). This work is in line with opinions from a number of researchers, that neuropsychological tests and their data should be shared and made available in order to facilitate scientific progress.

Currently there are major ongoing research projects about aging, physical and mental health, that collect multiple micro data including cognitive measures and other variables (for example, SHARE project (http://www.share-project.org/)). However, in such research there are constrains on how many cognitive measures can be used and usually processing speed is excluded. This and other similar research draws attention to importance of information processing speed in aging and mental illness.

Extended knowledge about information processing speed abilities, their features and correlates can be applied in practice. Correlates of IPS could allow optimization of work in professions requiring swift responses or decisions. Also, IPS assessment can be used in personnel selection or human recourse management. Furthermore, speedy and efficient information processing is essential in transportation.

In addition to what has been said it can be mentioned that study of IPS relations with other cognitive domains could be beneficial in understanding cognitive training. Currently, IPS based cognitive training programs become popular. Based on IPS research more efficient ways of helping traumatic brain injury and dementia patients could be developed.

The purpose of this study is to explore the factorial structure of information processing speed and to analyze how information processing speed along with memory and mental set-shifting are related to age, mental illness, also demographic, health and psychosocial variables.

Research questions

1. Does simple IPS and complex IPS factor structure best fits the data for very young adults, young adults, middle aged people, people with mental illness and healthy adult groups?
2. How is age related to simple IPS, complex IPS, memory and mental set-shifting abilities?
3. How is mental illness related to simple IPS, complex IPS, memory and mental set-shifting abilities?
4. How are simple IPS, complex IPS, memory and mental set-shifting abilities predicted by demographic, health and psychosocial variables?

5. Are age and mental illness relations with simple IPS, complex IPS, memory and mental set-shifting abilities mediated or moderated by demographic, health and psychosocial variables?
6. How are simple IPS, complex IPS, memory and mental set-shifting abilities predicted by age, mental illness, demographic, health and psychosocial variables in a general model?

Propositions to be defended

1. Simple IPS and complex IPS factor structure best fits the data for very young adults, young adults, middle aged people, people with mental illness and healthy adult groups.
2. Simple IPS, complex IPS, memory and mental set-shifting are directly and indirectly predicted by age, mental illness, also demographic, health and psychosocial factors.
3. Relationship of age and mental illness with simple IPS, complex IPS, memory and mental set-shifting is mediated and/or moderated by demographic, health and psychosocial factors
4. Simple IPS is a very important mediator in relationship between prognostic variables, such as age or mental illness, and cognitive abilities.

METHODOLOGY

Participants and procedures

The final sample was composed of 556 subjects. Study sample was a convenience sample. Overall, the sample was mostly comprised of women (63.8 %), ages from 18 to 65 years (M = 33.60, SD = 12.86), they were Lithuanian native speakers (85.3 %), working (50.2 %) and single (not married and doesn't live with a partner, 41.4%). All participants spoke Lithuanian, had normal or corrected eyesight, did not have self-reported hand injuries, and gave verbal informed consent. The study in clinical inpatient groups was approved by the Bioethics Committee, Vilnius University Faculty of Medicine (No. 158200-15-788-328). The Control Group (CG) (N = 381) was an opportunistic sample of students from Vilnius University and Lithuanian University of Educational Sciences and mostly their family, relatives and friends who did not report any history of mental or neurological disorders and completed a full neuropsychological test battery. General clinical sample of mental illness was composed of three smaller samples. The first clinical sample (N = 33) was comprised of individuals with self-reported history of mental disorder also selected during the same sampling procedure as the control group, but reporting a history of mental disorder diagnosis in adulthood. Individuals in this group most frequently reported having a diagnosis of depression. The second clinical sample (N = 35) was comprised of individuals who were diagnosed with mild-moderate (F10-F99, except F20-F29) mental disorder who were treated in mental health center during testing, all of these patients were having psychopharmacological treatment. Most of the participants were diagnosed with depression (F32). The third clinical sample was comprised of individuals who were diagnosed with severe (F20-F29) mental disorder who were treated in mental health center, all of these patients were also having psychopharmacological treatment and were much less likely to receive psychotherapeutic treatment than the second clinical sample. Most of the participants in this group were diagnosed with paranoid schizophrenia (F20.0). The groups did not differ in age, years of education or gender proportion.

Instruments

Neuropsychological test battery that is used in this study was designed to measure simple IPS, complex IPS, memory and set-shifting cognitive ability domains. Overall participants completed eleven PEBL (The Psychology Experiment Building Language) open source software (Mueller, 2010; Mueller & Piper, 2014) based computer administered tasks.

Simple information processing speed:

- Rotor pursuit task (RPT) is a sensimotor and hand-eye coordination ability dependent task (Larrabee, 2014). Subjects are asked to track a red circle moving steadily around a circular path and keep a mouse button on the path at all times.
- Finger tapping test (FTT) is a classical simple motor skill task (Witt, Laird, & Meyerand, 2008). Subjects are asked to tap the keyboard button as quickly as possible. There are 2 10-second dominant hand and 2 10-second non-dominant hand trials. FTT score is the mean number of taps in all four trials.
- Choice reaction time task (CRT) is a commonly used reaction time task (e.g., Albinet, Boucard, Bouquet, & Audiffren, 2012). Participants have to respond as quickly and accurately as possible to a visually-displayed arrow oriented to the right or to the left, by pressing the spatially-compatible key.

Complex information processing speed:

- Lexical decision task (LDT) measures lexical retrieval speed (Wagenmakers et al., 2008). Participants have to respond as quickly and accurately as possible to a visually-displayed words or nonwords (misspelled words), by pressing the right key if a word is written correctly and left key if it is not a word.
- Semantic categorization task (SCT) measures semantic processing speed (Wagenmakers et al., 2008). First, subject is presented with a category word (e.g., animal, furniture, clothes) and after a 350 ms period, one by one, eight words are presented that belong or don’t belong to this category. Participants have to respond as

quickly and accurately as possible to a visually-displayed words by pressing right key if a word belongs to the category and left key if it does not.

- Object judgement task (OJT) measures speed of generation and manipulation of visual images (Jordan, Heinze, Lutz, Kanowski, & Jäncke, 2001). Stimuli in this test are Attneave shapes (Mueller, 2010). The subject is shown a study shape, followed shortly afterwards by another shape. The second shape can be either same as the study shape but rotated or a different shape. Participants have to respond as quickly and accurately as possible by pressing the right key if the same as the study shape is presented and the left key if it is a different shape.
- The Tower of London (TOL) move time measure was used to measure the planning speed (Anderson, Anderson, & Lajoie, 2010). Subjects were asked to move a pile of disks from their original configuration to the configuration shown on the top of the screen. They were asked to do the task as quickly and with as little moves as they can.

Memory abilities:

- Forward digit span (FDS) measures the short-term memory span for digits (St Clair-Thompson & Allen, 2013). The subject is presented with a sequence of digits, one at a time on the screen. Each digit occurs only once during a list. The participant is then asked to type the list of digits exactly in the order as it was shown. The shortest list length is three digits. The task gradually becomes harder. Participants have 2 trials at each length. FDS score is the number of correct answers.
- Corsi block test (CST) is a visuospatial working memory task (Mueller & Piper, 2014). During this task, nine blue squares are presented on the screen. On each trial, the squares light up one at a time in a sequence. The participant is asked to remember this sequence. When the sequence is finished, the participant is asked to click on each square in the same order as it was presented. The shortest sequence length is two. The task gradually becomes harder. Participants have 2 trials at each sequence length. CST score is the number of correct answers.
- Yes/No recognition test (YNR) is a verbal recognition task (Khoe, Kroll, Yonelinas, Dobbins, & Knight, 2000). In the encoding phase of this test, the subject is

presented with a sequence of 14 words, one at a time on the screen. After seven tasks (approximately 30 minutes) in the recognition phase, the subject is presented with 45 words one by one and is asked to press the right key if the word was presented in the recognition phase and the left key if it was not.

Mental set-shifting:

- Berg "Wisconsin" Card Sorting Test (BCST) is a measure of set-shifting ability to generally associated with broader cognitive domains of reasoning, learning and executive control (Mueller & Piper, 2014). The subject is asked to categorize the cards based on the pictures appearing on them. The correct answer depends upon a rule, which the subject does not know. At each trial, feedback is presented. After ten correct responses, the rule that determines correct answer changes, so the subject must figure out what the rule is as quickly as possible and change with it. BCST scores are the number of correct responses (BCST-c) and the number of unique errors that do not match any categorization (BCST-u).

In order to test the construct validity of composite scores, confirmatory factor analysis was performed. Before conducting this structural equation modelling-based analysis, non-normal distributions of raw scores were transformed using logarithmical (YNR, BCST-c, LDT) or inverse (TOL, SCT, CRT, BCST-u, OJT) transformations (Tabachnick & Fidell, 2013). Four-factor solution yielded results ($\chi^2 = 129.724$; df = 46; $p < 0.001$; RMSEA = 0.063; CFI = 0.959; TLI = 0.942) best fitting data in comparison to other possible models. Test-retest reliability of these composite scores in student sample is satisfactory for set-shifting and high for memory, simple and complex IPS.

Big Five Inventory – Neuroticism:

In order to assess Neuroticism, we used Big Five Inventory (BFI) neuroticism scale (John, Naumann, & Soto, 2008). Cronbach's internal consistency was high (Cronbach $\alpha = 0.808$). Test-retest reliability was also high (ICC = 0.859, $p < 0.001$). Confirmatory factor analysis was used in order to determine one factor structure. Factor loadings ranged from 0.524 to 0.673. Model fit the data ($\chi2 = 59.872$; df = 14; $p < 0.001$; RMSEA

= 0.077; CFI = 0.954; TLI = 0.930), based on commonly used criteria (CFI > 0.90; TLI > 0.90; RMSEA < 0.10) (Pakalniškienė, 2013).

Subjective social connectedness:

In order to assess the overall quality and quantity of relationships that individuals experience (Mitchinson, Kim, Geisser, Rosenberg, & Hinshaw, 2008), a 7 item questionnaire was constructed. Cronbach internal consistency was satisfactory (Cronbach $\alpha = 0.648$). Test-retest reliability was high ($ICC = 0.862$, $p < 0.001$). Confirmatory factor analysis was used in order to determine one factor structure. Factor loadings ranged from 0.283 to 0.587. Model fit the data ($\chi 2 = 30.184$; $df = 11$; $p < 0.001$; RMSEA = 0.056; CFI = 0.956; TLI = 0.916), based on commonly used criteria (CFI > 0.90; TLI > 0.90; RMSEA < 0.10) (Pakalniškienė, 2013).

Subjective socioeconomic status:

5 item scale was used to assess to assess subjective beliefs about socioeconomic status. Cronbach internal consistency was satisfactory (Cronbach $\alpha = 0.680$). Test-retest reliability was high ($ICC = 0.748$, $p < 0.001$). Confirmatory factor analysis was used in order to determine one factor structure. Factor loadings ranged from 0.327 to 0.741. Model fit the data ($\chi 2 = 20.624$; $df = 4$; $p < 0.001$; RMSEA = 0.087; CFI = 0.965; TLI = 0.912), based on commonly used criteria (CFI > 0.90; TLI > 0.90; RMSEA < 0.10) (Pakalniškienė, 2013).

Health variables:

Information about health status was collected. Study participants reported subjective physical and mental health on a 6-point scale from very poor to very good. Also, they were asked for a number of days they spent in work leave and their working capacity. Moreover, subjects reported their height and weight in order to calculate body-mass index.

Demographic variable:

Subjects were asked to report age, gender, first language, working status, family status, education and neurological or mental illness diagnosis.

Data analysis

The data were analyzed using IBM SPSS 22, AMOS 22, and PROCESS. To compensate for non-normal distributions, we used data transformations (Tabachnick & Fidel, 2013). Data analysis included descriptive statistics, Pearson's correlation, Student's t test, hierarchical linear regression, confirmatory factor analysis and path analysis. PROCESS was used for mediational and moderational analysis (Hayes, 2012).

THE MAIN RESULTS

The structure of information processing speed measures

The structure of information processing speed was analyzed by confirmatory factor analysis (CFA). The estimation method was the Maximum Likelihood. Four theory based models of information processing speed structure were derived from the literature and compared using CFA method (Pakalniškienė, 2013). Model 1 consisted of one factor which was associated with all seven measures of information processing speed and it was based on a premise that relationships between measures of speed can best be described by one factor structure (Salthouse, 2000, Deary & Stough, 1996; Bors & Forrin, 1995; Carroll, 1993; Catts, Gillispie, Leonard, Kail, & Miller, 2002; Helmbold, Troche, & Rammsayer, 2007). Model 2 consisted of two factors. In this model information processing speed is divided into simple IPS and complex IPS as proposed by Cepeda, Blackwell & Munakata (2013). Simple IPS refers to the speed of relatively simple and basic motor, perceptual and other reaction time tasks and complex IPS involves speed of relatively complex lexical, semantic, visuospatial or executive tasks. The first factor in this model was associated with Rotor pursuit task, Finger tapping and Choice reaction time task. Factor two was associated with Lexical decision task, Semantic categorization task, Object judgment task and Tower of London speed task. Model 3 was also based on research indicating psychomotor and cognitive speed being separate (Birren & Fisher, 1995). In this model factor one is composed of Rotor pursuit task and Finger tapping task, and factor two is composed of Choice reaction time task, Lexical decision task, Semantic decision task, Object judgment task and Tower of London speed task. Model 4 was composed of two factors. It was based on literature comparing verbal and nonverbal information processing differences in cognition and analyzing their biological underpinnings (Lawrence, Myerson, & Hale, 1998). Verbal speed factor was composed of Lexical decision task and Semantic decision task, and Nonverbal speed factor was composed of Rotor pursuit task, Finger tapping, Choice reaction time task, Object judgment task and Tower of London speed task.

All four structural models of information processing speed were compared (Table 1). However, chi-square difference test could be done only when comparing one model 1 with other two factor models as all two factor models had equal degrees of freedom. Comparison of one and two-factor models showed that all three two-factor models fit the data significantly better ($p < 0,05$) than Model 1. Model 2, Model 3 and Model 4 there compared using Akaike information criterion (AIC) (Čekanavičius ir Murauskas, 2009). Model 2 which is composed of simple IPS and complex IPS and Model 3 which is composed of verbal IPS and nonverbal IPS fit the data equally well based on AIC criteria (>10 AIC difference is substantial; >4 considerably more fitting model (Burnham & Anderson, 2002). However, even these two models did not satisfy minimum fit criteria recommended in the literature (RMSEA < 0.08; CFI > 0.900; TLI > 0.900) (Čekanavičius ir Murauskas, 2009), so models were modified by allowing measurement errors between tasks to correlate. Based on modification indices and theoretical considerations two correlations were added: Rotor pursuit task with Tower of London and Choice reaction time task with Lexical decision task.

Table 1. Fit indices for confirmatory factor analysis models of information processing speed measures

Modelis	χ^2	df	p	CFI	TLI	RMSEA	AIC
Model 1	200,574	14	< 0,001	0,872	0,808	0,155	228,57
Model 2	135,723	13	< 0,001	0,962	0,864	0,130	165,72
Model 3	168,027	13	< 0,001	0,894	0,828	0,147	198,03
Model 4	139,188	13	< 0,001	0,914	0,860	0,132	169,19

Note. CFI: comparative fit index; TLI: Tucker-Lewis index; RMSEA: Root Mean Square Error of Approximation; AIC: Akaike's information criterion. Model 1 – general information processing speed one factor model; Model 2 – simple IPS/complex IPS two-factor model; Model 3 – psychomotor processing speed/cognitive speed two factor model; Model 4 – verbal/nonvebal speed two factor model.

Rotor pursuit task and Tower of London allowing measurement errors were allowed to correlate based on the fact that in both of these tasks but not in others precise computer mouse control was important. On the other hand, Choice reaction time task measurement error was allowed to correlate with Lexical decision task because measurement error had negative relationship. This phenomenon is thought to have appeared due to the fact that these tasks had very similar instructions. It is likely that a small portion of subjects who made more errors in the first task (Choice reaction time task) corrected themselves and made less errors in the second task (Lexical decision task) consequently becoming slower.

Fit indices were recalculated after modifications for each model (Table 2). Comparison of modified one and two-factor models showed that all three two-factor models fit the data significantly better ($p < 0.05$) than modified Model 1. Modified Model 2 which is composed of simple IPS and complex IPS fit the data best out all two factor models. Modified Model 2 did satisfy minimum fit criteria recommended in the literature (RMSEA < 0.08; CFI > 0.900; TLI > 0.900) (Čekanavičius ir Murauskas, 2009).

Table 2. Fit indices for confirmatory factor analysis modified models of information processing speed measures

Modified models	χ^2	df	p	CFI	TLI	RMSEA	AIC
Model1	98,312	12	< 0,001	0,941	0,897	0,114	130,312
Model 2	43,346	11	< 0,001	0,978	0,958	0,073	77,35
Model 3	56,015	11	< 0,001	0,969	0,941	0,086	90,02
Model 4	83,249	11	< 0,001	0,951	0,906	0,109	117,30

Note. CFI: comparative fit index; TLI: Tucker-Lewis index; RMSEA: Root Mean Square Error of Approximation; AIC: Akaike's information criterion. Model 1 – general information processing speed one factor model; Model 2 – simple IPS/complex IPS two-factor model; Model 3 – psychomotor processing speed/cognitive speed two factor model; Model 4 – verbal/nonvebal speed two factor model.

Simple IPS and complex IPS constructs in the best fitting model (Model 2) appear to be distinct despite high correlations between two factors (Figure 1). Model where relationship between two factors $r = 1$ was significantly different compared to model where factors could covariate freely (chi square difference equal to 47,026; $df = 1$; $p < 0,001$). So, the relationship between two factors was significantly smaller than 1. This was described by Salthouse (1993), when analyzing differences between motor and perceptual speed factors. It was noted that although measures of speed are highly correlated they seem to describe more than one construct.

Chiaravalloti et. al. (2003) research is one of a few where simple and complex information processing factors are described. In Chiaravalloti et. al. (2003) study simple IPS was composed of reaction time tasks, however not psychomotor tasks. Also, in our study we use both verbal and nonverbal tasks to measure complex IPS. The major advantage of our study is the large variety of different speed tasks. Due to this variety we can state with greater certainty that, as theorized, information processing speed has a two factor structure based not on modality but on complexity of information.

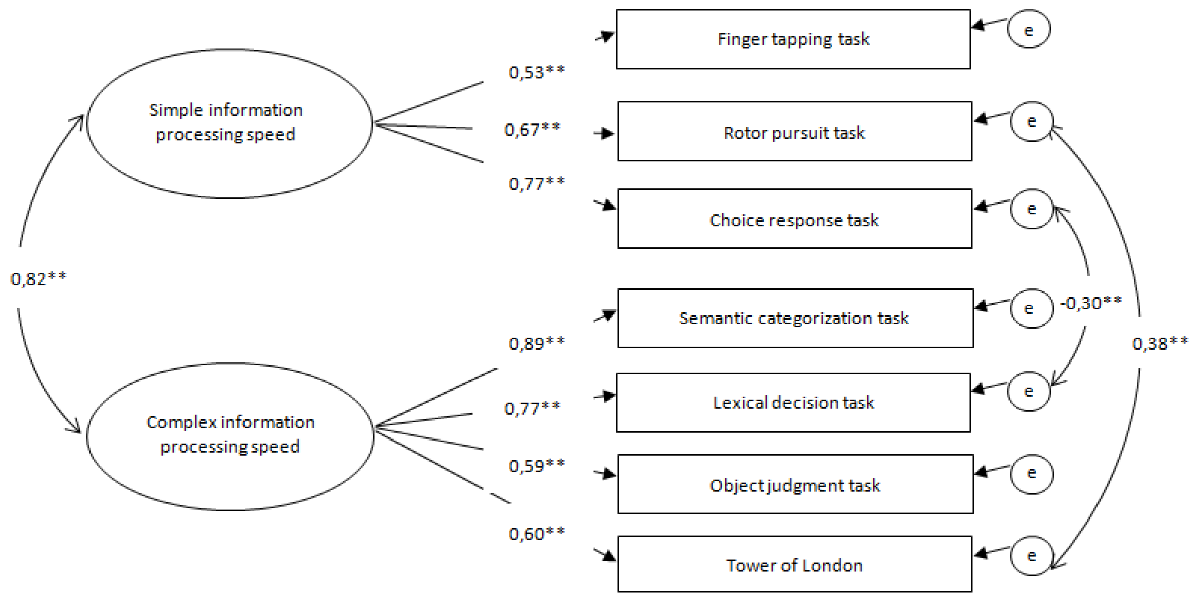


Figure 1. Results for two-factor solution representing simple IPS and complex IPS

In this model, the simple processing speed measure with the highest factor loading was the choice reaction time task. Choice reaction time task is a gold standard for measuring processing speed. In this task there are two possible stimuli and two possible responses (Miller, & Low, 2001). Traditionally, reaction time paradigms are used almost as a synonym for information processing speed. High factor loading of this task can probably be explained by its simplicity and accuracy in measurement and also simultaneous use of perceptual, motor and cognitive abilities while performing this task. Choice reaction time as a processing speed measure fits the definition of processing speed as time taken to perform relatively simple motor, perceptual and other cognitive operations (Salthouse, 2000).

It is interesting that the highest factor loading in complex information processing speed factor was for Semantic categorization task which was relatively easier compared to Tower of London performance speed task which is usually used to measure executive planning abilities. On the other hand, it has been suggested that semantic categorization task can be defined as an important measure of decision speed in a general processing speed factor (McGrew & Evans, 2004). It might be suggested that this task encompasses the largest variety of different relatively complex cognitive operations such as fast reading, comprehension, category visualization, taking into account previous items in the list. High loading of semantic categorization task also adds more doubt about the hypothesis that complex information processing speed can be defined as executive control speed (Cepeda, Blackwell, & Munakata 2013).

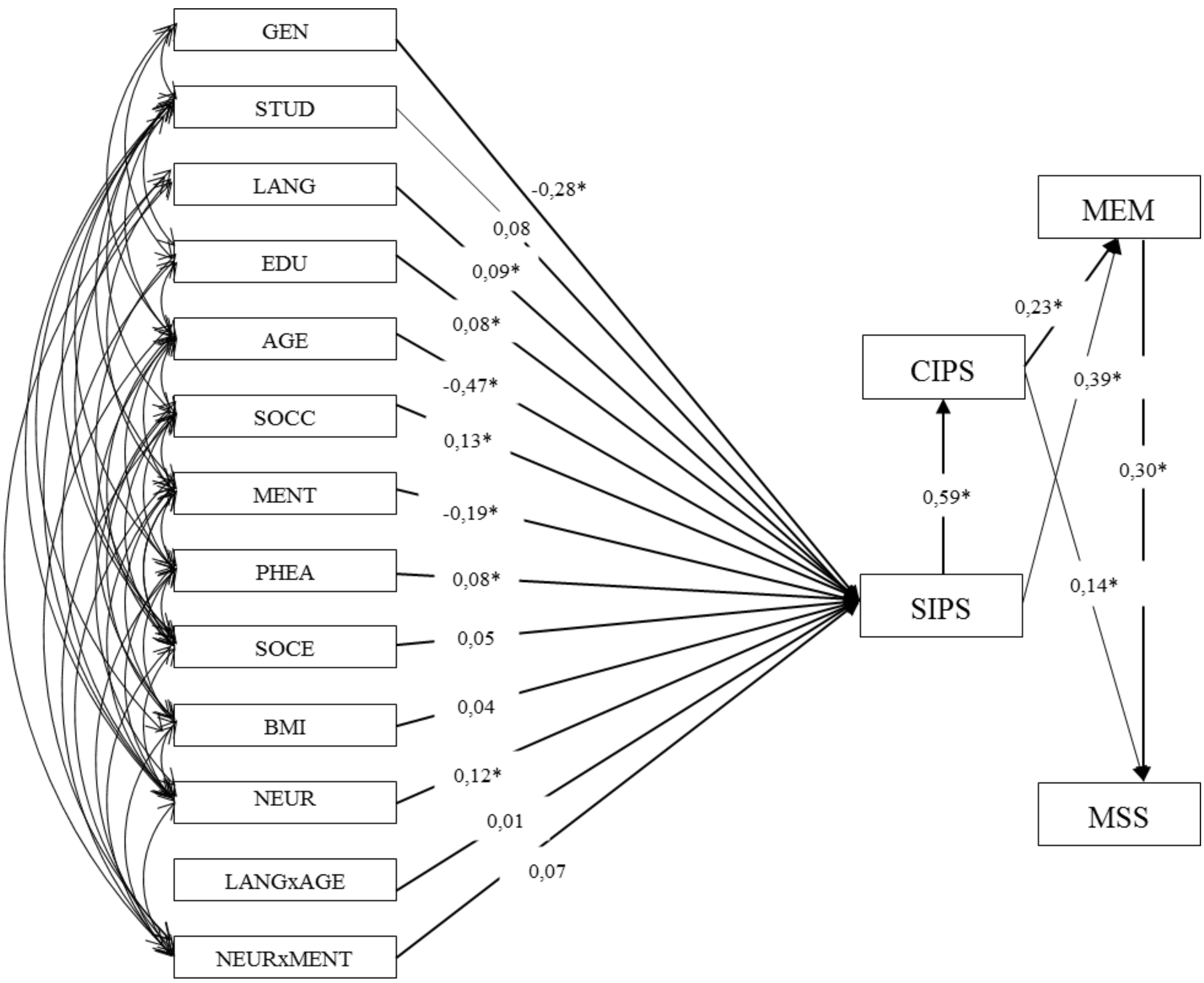
Varying complexity and modality of information processing speed measures was used in this study. However, in order to suggest that information processing speed has a two factor structure of simple IPS and complex IPS still further research is needed. First of all, a larger sample of IPS measures should be used. Second, paper-pencil measures of IPS should also be included in further studies as they might have different psychometric properties.

Prognostic models of information processing speed and other cognitive domains

After determining the structure of information processing speed measures we sought to construct a prognostic model of information processing speed and other cognitive abilities. Using structural equational modeling, two general models based on different theoretical assumptions with demographic, health and psychosocial as predictive variables were evaluated.

First, a model was tested in which age, mental illness and also demographic, health and psychosocial variables predict cognitive abilities through simple processing speed as a mediator (Figure 2). This model is based on an assumption that simple processing speed might work as a global mediator determining individual differences in other cognitive domains. Processing speed can be understood like a central processing unit in the brain (Kail, 1992). Furthermore, other theoretical and empirical considerations were taken into account when constructing this model: a) information processing speed has a two factor structure; b) Salthouse (1996) theory can be used in explaining relationship between fluid abilities and mental illness; c) simple information processing speed mediates the relationship between age and complex information processing speed; d) memory abilities partially mediate relationship between information processing speed and mental set-shifting ability.

In this model all the variables that are prognostic of cognitive abilities and also moderations or interactions have been used. Prognostic variables were allowed to covary (Tabachnick & Fidell, 2013). Model did not satisfy all fit criteria: χ^2 = 191,636; df = 72; p = < 0,001; TLI = 0,899; CFI = 0,947; RMSEA = 0,055 AIC = 353,636. Conclusion can be drawn that a model in which age, mental illness and also demographic, health and



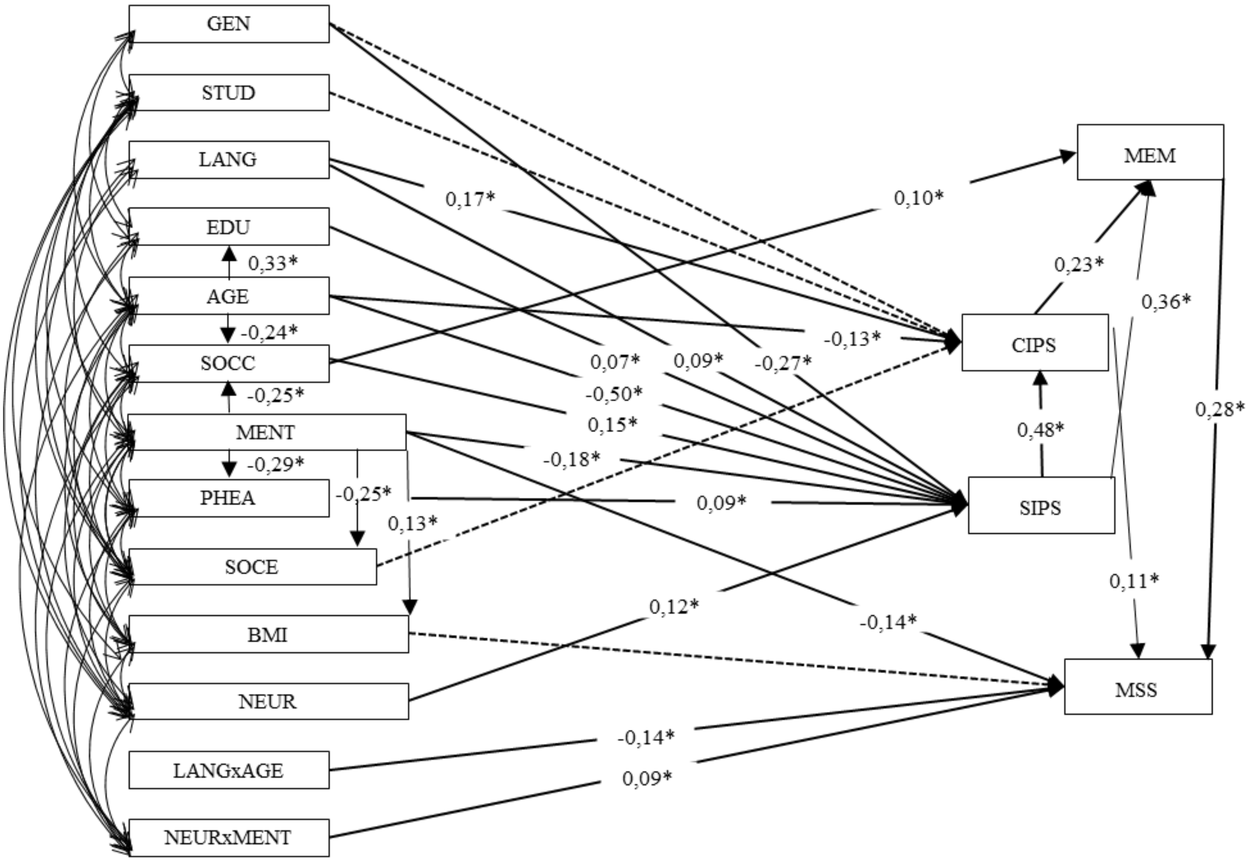
Note. SIPS: simple information processing speed; CIPS: complex information processing speed; MEM: memory abilities; MSS: mental set-shifting ability; GEN – gender; STUD – studying at the moment; LANG – native language; EDU - education; SOCC – subjective social connectedness; MENT – mental illness; PHEA – subjective physical health; SOCE – subjective socioeconomic status; BMI – body-mass index; NEUR – neuroticism; LANGxAGE – native language and age interaction effect; NEURxMENT – neuroticism and mental illness interaction effect. * p < 0,05; ** p < 0,01.

Figure 2. Path analysis model in which age, mental illness and also demographic, health and psychosocial variables predict cognitive abilities through simple processing speed

psychosocial variables predict cognitive abilities through simple processing speed was not a good fit for the data. So, it can be said that simple IPS does not work as a central processor mediating individual differences in other cognitive domains (Kail, 2008). However, it should be noted that in this model where simple IPS was a single mediator a large proportion of variances in cognitive domains was explained (47,3 % of simple IPS; 35,1 % of complex IPS; 31,6 % of memory domain; and 15,0 % of mental set-shifting). So, although the analysis of the data suggested that this model did not satisfy fit criteria, it shows that simple IPS is a very important domain in cognition. This is supported by cognitive theories and models integrating IPS as an import part of human cognitive structure (Salthouse 1996, Miller, 2013, DeLuca 2012, Anderson, 2003, Anderson 2001). On a neurobiological level the importance of IPS has been shown in aging (Salami, Eriksson, Nilsson & Nyberg, 2012) and mental illness (Antonova et. al., 2005).

In order to develop a more fitting model aposteriori modifications were made. First, nonsignificant paths predicting simple IPS were removed. Second, based on theoretical considerations and modification indices direct paths from independent variables to cognitive abilities were added. The final path model (Figure 3) satisfied all fit criteria: $\chi^2 = 111{,}113$; df = 67; p = 0,001; TLI = 0,960; CFI = 0,980; RMSEA = 0,034; AIC = 283,113. This model explains 46,6 % of simple information processing speed variance, 40,6 % of complex information processing speed variance, 32,4 % of memory ability variance and 18,8 % of mental set-shifting variance. The difference of model fit based on Chi-square difference test was assessed. Final model fit the data significantly better ($\Delta\chi^2 = 80{,}523$; df = 5; $p < 0{,}001$) than model in which simple information processing speed mediated all dependent and independent variable relationships.

In the final model, age and gender were the strongest predictors of simple IPS. Simple IPS was also predicted by native language, education, subjective social connectedness, mental illness and neuroticism. Complex IPS was most predicted by simple IPS and native language and also by age. Memory was predicted by simple IPS and complex IPS and also by subjective social connectedness. Mental set-shifting was predicted by memory, mental illness and interaction between native language and age.



Note. SIPS: simple information processing speed; CIPS: complex information processing speed; MEM: memory abilities; MSS: mental set-shifting ability; GEN – gender; STUD – studying at the moment; LANG – native language; EDU - education; SOCC – subjective social connectedness; MENT – mental illness; PHEA – subjective physical health; SOCE – subjective socioeconomic status; BMI – body-mass index; NEUR – neuroticism; LANGxAGE – native language and age interaction effect; NEURxMENT – neuroticism and mental illness interaction effect. * p < 0,05; ** p < 0,01.

Figure 3. Path analysis model in which age, mental illness and also demographic, health and psychosocial variables directly and indirectly predict cognitive abilities

In this study we suggest that complex IPS, memory and mental-set shifting relates to age, mental illness, demographic, health and psychosocial variables independently of simple IPS due to cognitive strategies that are being employed in complex tasks but not in tasks of simple IPS. The effect of cognitive strategies has been suggested by many authors. For example, Lawrence, Myerson & Hale (1998) proposed that verbal tasks require knowledge and are processed in qualitatively different neural networks. Also, Cepeda, Blackwell & Munakata (2013) study indicate that complex speed tasks are strongly related to executive control. Furthermore, Salthouse (1996) described limited time and simultaneity mechanisms that differentiate memory and complex reasoning tasks from speed tasks which do not require task specific cognitive mechanism such as recall or visual manipulation. Other cognitive models (Miller, 2013, DeLuca 2012, Anderson, 2003, Anderson 2001) suggest important additional cognitive mechanisms that are used in complex but not simple psychomotor tasks, such as, for example, cognitive control system, central executive, independent processing units, phonological loop, episodic buffer or visuospatial sketchpad. These theoretical approaches and empirical findings are consistent with a view that performance of complex IPS, memory or set-shifting tasks allow additional cognitive strategies which can be related to age, mental illness, demographic, health or psychosocial variables (Adam et. al., 1999, Stern, 2009, Westerberg & Klingberg, 2007, Eckert, 2011).

In this study, it is shown that simple IPS is an important ability in describing cognitive structure. Simple IPS is predicted by age (partly mediated by social connectedness and education), mental illness (partly mediated by subjective physical health and social connectedness) and gender, and also by native language and neuroticism. However, high predictive power of simple IPS on other cognitive domains does not suggest that simple IPS defines all individual differences in higher cognition. Quite the contrary, it can be hypothesized that simple IPS only predict those individual differences that are related to significant changes in nervous system, for example aging process or mental illness. On the other hand, for example, educational attainment or work efficiency, would be best predicted by executive, memory or other cognitive domains related to complex processing. “Higher” or more complex abilities such as memory or mental set-shifting are much more specific and could even be independent of g factor (Anderson, 2001). Furthermore, this study is in agreement with dedifferentiation hypothesis suggesting that specific cognitive abilities become more highly associated due to aging as a result of increasing biological constraints on fluid abilities (Li, Lindenberger & Sikström, 2001). So it could be suggested that in aging or mental illness more complex abilities are worse at describing cognitive decline.

Our finding show that despite mediation effect of simple IPS, complex IPS was independently related to age and native language. This result is supported by existing findings that people of different ages (Eckert, 2011) and language abilities (Kranzler, Flores, & Coady, 2010) use different cognitive strategies in complex problems. Thus, despite strong relationship between complex IPS and simple IPS, these are different domains predicted by different independent variables. Further research is needed to clarify these differences.

Social connectedness was the only independent variable in the final model predicting memory abilities when relationships with simple IPS and complex IPS were accounted for. Thus it can be hypothesized that simple IPS and complex IPS mediating effect on age-memory relationship might be explained by limited time and simultaneity mechanisms (Salthouse, 1996). Also, these mechanisms could be related to memory slave systems described by Baddley (2001). On the other hand, social connectedness is a mediator in age-memory relationship so it can be suggested that the contribution of social connectedness is based on declined use of memory abilities in older age.

Independently of variance explained by other cognitive domains mental illness was prognostic of mental set-shifting, and this relationship was partially moderated by neuroticism. Previous results concerning Wisconsing card sorting test support the relationship between mental set-shifting and mental illness (Rady et. al., 2012). It seems that neuroticism might play a role in this relationship. Further analysis is needed.

Although body-mass index and socioeconomic status were predictive in mediational and regression analysis, in the final model they did not account for any additional variance. This study is limited by its cross-sectional design. Many independent variables were intercorrelated so weak relationships should be interpreted carefully.

To conclude, model in which age, mental illness and also demographic, health and psychosocial variables predict cognitive abilities through simple processing speed did not fit the data. Final model revealed a complex pattern of relationships between cognitive domains and age, mental illness, also demographic, health and psychosocial variables. Simple IPS is a fundamental part of cognitive structure. However, it is not a global mediator for individual differences. Both, simple IPS and complex IPS are very important in explaining aging, mental illness, also individual differences related to demographic, health and psychosocial variables.

CONCLUSIONS

1. Information processing speed (IPS) among adults is best explained by structure of two factors: simple IPS and complex IPS. This information processing speed structure is invariant across mental illness and control samples and age groups.
2. Age directly and indirectly predict simple IPS and complex IPS speed also memory and set-shifting abilities.
   - 2.1. In a model of age differences in cognition, age and simple IPS, age and complex IPS, age and memory abilities, simple IPS and memory, simple IPS and complex IPS, complex IPS and mental set-shifting, complex IPS and memory, also memory and mental set-shifting were directly related.
   - 2.2. Based on estimation of direct and indirect effects simple IPS is the strongest mediator of age relations with other cognitive domains.
3. People with mental illness showed worse performance on simple IPS, complex IPS, memory and mental set-shifting. Mental illness directly and indirectly related to cognitive domains.
   - 3.1. In a model of mental illness and cognition relations mental illness and simple IPS, mental illness and complex IPS, mental illness and mental set-shifting, simple IPS and memory, simple IPS and complex IPS, complex IPS and mental set-shifting, complex IPS and memory, also memory and mental set-shifting were directly related.
   - 3.2. Based on estimation of direct and indirect effects simple IPS is the strongest mediator of mental illness relations with other cognitive domains.
4. Cognitive abilities were predicted by demographic, health and psychosocial variables.
   - 4.1. Men performed better than women on simple IPS and memory tasks. Subjects that currently study were better in memory and complex IPS tasks. Subjects whose native language was Lithuanian were better at simple IPS and complex IPS tasks. Education is related to simple IPS and memory.
   - 4.2. Worse self-rated physical health is related to worse performance on simple IPS tasks. Body-mass index is related to mental set-shifting.

4.3. Subjective social connectedness is a predictor of simple IPS and memory. Neuroticism is a predictor of simple IPS. Subjective socioeconomic status is a predictor of complex IPS.

5. Age and mental illness relationships with cognitive abilities are mediated or moderated by demographic, health and psychosocial variables.
   5.1. Age relationship with cognitive abilities is partially mediated by education and subjective social connectedness.
   5.2. Mental illness relationship with cognitive abilities is partially mediated by subjective physical health, body-mass index, subjective social connectedness and subjective socioeconomic status.
   5.3. Age relationship with mental set-shifting is moderated by native language.
   5.4. Simple IPS, complex IPS and mental set-shifting relations with mental illness are moderated by neuroticism.
6. Final model fit the data better than a model where simple IPS is the only mediator of relationship between prognostic factors and cognitive function. However, in the final model most prognostic factors predicted complex IPS, memory and metal set-shifting through simple IPS.

REFERENCES

Adam, J. J., Paas, F. G., Buekers, M. J., Wuyts, I. J., Spijkers, W. A., & Wallmeyer, P. (1999). Gender differences in choice reaction time: evidence for differential strategies. Ergonomics, 42(2), 327–335. doi:10,1080/001401399185685

Albinet, C. T., Boucard, G., Bouquet, C. A., & Audiffren, M. (2012). Processing speed and executive functions in cognitive aging: How to disentangle their mutual relationship? Brain and Cognition, 79(1), 1–11. doi:10,1016/j.bandc.2012.02.001

Anderson, M. (2001). Conceptions of Intelligence. Journal of Child Psychology and Psychiatry, 42(3), S0021963001007016. doi: 10,1017/S0021963001007016

Anderson, P. (2003). Assessment and Development of Executive Function (EF) During Childhood. Child Neuropsychology. doi: 10,1076/chin.8.2.71.8724Anderson, 2015

Anderson, P., Anderson, V., & Lajoie, G. (1996). The tower of London test: Validation and standardization for pediatric populatons. The Clinical Neuropsychologist, 10(1), 54–65. doi:10.1080/13854049608406663

Antonova, E., Kumari, V., Morris, R., Halari, R., Anilkumar, A., Mehrotra, R., & Sharma, T. (2005). The relationship of structural alterations to cognitive deficits in schizophrenia: A voxel-based morphometry study. Biological Psychiatry, 58(6), 457–467. doi: 10,1016/j.biopsych.2005.04.036

Baddeley, A. D. (2001). Is working memory still working? American Psychologist, 56(11), 851–864. doi:10,1037/0003-066x.56.11.851Barrett, 2008

Birren, J. E., & Fisher, L. M. (1995). Aging and speed of behavior: possible consequences for psychological functioning. Annual Review of Psychology, 46(July 2015), 329–353. doi:10,1146/annurev.psych.46.1.329Borella, Ghisletta, & de Ribaupierre, 2011

Bors, D. A., & Forrin, B. (1995). Age, speech of information processing, recall, and fluid intelligence. Intelligence, 20 (3), 229–248. doi: 10,1016/0160-2896(95)90009-8.Bott et. al., 2014,

Burnham, K. P., Anderson, D. R. (2002) Model selection and multimodel inference: a practical information-theoretic approach (2nd ed.). New York: Springer. Carroll, 1993;

Catts, H. W., Gillispie, M., Leonard, L. B., Kail, R. V., & Miller, C. A. (2002). The Role of Speed of Processing, Rapid Naming, and Phonological Awareness in Reading

Achievement. Journal of Learning Disabilities, 35(6), 510–525. doi:10,1177/00222194020350060301.Cepeda, Blackwell, & Munakata 2013

Cepeda, N. J., Blackwell, K. A., & Munakata, Y. (2013). Speed isn’t everything: complex processing speed measures mask individual differences and developmental changes in executive control. Developmental Science, 16(2), 269–86. doi: 10,1111/desc.12024Chiaravalloti et. al. (2003)

Chiaravalloti, N. D., Christodoulou, C., Demaree, H. A., & DeLuca, J. (2003). Differentiating simple versus complex processing speed: influence on new learning and memory performance. Journal of Clinical and Experimental Neuropsychology, 25(4), 489–501. doi: 10,1076/jcen.25.4.489.13878Czaja & Lee, 2007

Čekanavičius V. ir Murauskas G. (2009). Statistika ir jos taikymas (III). Vilnius: TEV.

Deary, I., & Stough, C. (1996). Intelligence and inspection time: Achevements, prospects, and problems. American Psychologist, 51 (6), 599–608. doi: 10,1037//0003-066x.51.6.599

DeLuca, J. (2008). Information processing speed: How fast, how slow, and how come? In J. DeLuca & J. H. Kalmar (Eds.), Information processing speed in clinical populations (pp. 267-273). New York, NY: Taylor & Francis.Dodonova, & Dodonov, 2012

Dovydaitytė, E. (2016). Vykdomųjų funkcijų ir asmenybės savybių sąsajos (Bakalauro darbas). Vilnius: Vilniaus universitetas.

Eckert, M. A. (2011). Slowing down: Age-related neurobiological predictors of processing speed. Frontiers in Neuroscience, 5(MAR), 1–13. doi:10,3389/fnins.2011.00025Edwards et. al., 2009

Finch, C. E., & Zelinski, E. M. (2005). Normal aging of brain structure and cognition: Evolutionary perspectives. Research in Human Development, 2(1-2), 69–82. doi:10,1207/s15427617rhd0201&2_4

Gettman, M. T., Kondraske, G. V., Traxer, O., Ogan, K., Napper, C., Jones, D. B., … Cadeddu, J. A. (2003). Assessment of basic human performance resources predicts operative performance of laparoscopic surgery. Journal of the American College of Surgeons, 197(3), 489–496. doi:10,1016/S1072-7515(03)00333-8Grassi & Borella, 2013,

Gross, A. L., Rebok, G. W., Unverzagt, F., Willis, S. L., & Brandt, J. (2011). Cognitive predictors of everyday functioning in older adults: results from the ACTIVE Cognitive

Intervention trial. Journals of Gerontology, Series B: Psychological Sciences and Social Sciences, 66(5), 557–566. doi:10,1093/geronb/gbr033.Hayes, 2012

Helmbold, N., Troche, S., & Rammsayer, T. (2007). Processing of temporal and nontemporal information as predictors of psychometric intelligence: a structural-equation-modeling approach. Journal of Personality, 75(5), 985–1006. doi:10,1111/j.1467-6494.2007.00463.x.

Jeste, D. V, Depp, C. A., & Vahia, I. V. (2010). Successful cognitive and emotional aging. World Psychiatry : Official Journal of the World Psychiatric Association (WPA), 9(2), 78–84. doi: 10,1097/01.nmd.0000369417.73882.daJohn, Naumann, & Soto, 2008

Jordan, K., Heinze, H. J., Lutz, K., Kanowski, M., & Jäncke, L. (2001). Cortical activations during the mental rotation of different visual objects. NeuroImage, 13(1), 143–152. doi:10,1006/nimg.2000,0677

Kail, R., & Salthouse, T. (1994). Processing speed as a mental capacity. Acta Psychologica, 86, 199-225. doi: 10,1016/0001-6918(94)90003-5.Kail, 2008

Kaufman, S. B., DeYoung, C. G., Gray, J. R., Brown, J., & Mackintosh, N. (2009). Associative learning predicts intelligence above and beyond working memory and processing speed. Intelligence, 37(4), 374–382. doi:10.1016/j.intell.2009.03.004

Kennedy, Q., Taylor, J., Heraldez, D., Noda, A., Lazzeroni, L. C., & Yesavage, J. (2013). Intraindividual Variability in Basic Reaction Time Performance. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 68(4), 487–494. doi:10,1093/geronb/gbs090

Khoe, W., Kroll, N. E. A., Yonelinas, A. P., Dobbins, I. G., & Knight, R. T. (2000). The contribution of recollection and familiarity to yes- no and forced-choice recognition tests in healthy subjects and amnesics. Neuropsichologia, 38(10), 1333–1341. doi: 10,1016/S0028-3932(00)00055-5.

Kochunov, P., Thompson, P. M., Winkler, A., Morrissey, M., Fu, M., Coyle, T. R., … Hong, L. E. (2016). The common genetic influence over processing speed and white matter microstructure: Evidence from the Old Order Amish and Human Connectome Projects. NeuroImage, 125, 189–197. doi: 10,1016/j.neuroimage.2015.10,050

Kranzler, J. H., Flores, C. G., & Coady, M. (2010). Examination of the Cross-Battery Approach for the Cognitive Assessment of Children and Youth From Diverse Linguistic and Cultural Backgrounds. School Psychology Review, 39(3), 431–446.

Lang, J. W. B., Kersting, M., Hulsheger, U. R., & Lang, J. (2010). General Mental Ability, Narrower Cognitive Abilities, and Job Performance: the Perspective of the Nested-Factors Model of Cognitive Abilities. Personnel Psychology, 63(3), 595–640, doi: 10,1111/j.1744-6570,2010,01182.x

Larrabee, G. J. (2014). Test validity and performance validity: considerations in providing a framework for development of an ability-focused neuropsychological test battery. Archives of Clinical Neuropsychology : The Official Journal of the National Academy of Neuropsychologists, 29(7), 695–714. doi:10,1093/arclin/acu049

Laurence, J. H., & Matthews, M. D. (2012). The Oxford Handbook of Military Psychology. The Oxford Handbook of Military Psychology. doi:10,1093/oxfordhb/9780195399325.001.0001

Lawrence, B., Myerson, J., & Hale, S. (1998). Differential Decline of Verbal and Visuospatial Processing Speed Across the Adult Life Span. Aging, Neuropsychology, and Cognition (Neuropsychology, Development and Cognition: Section B), 5(2), 129–146. doi:10.1076/anec.5.2.129.600

Lee, T., Mosing, M. A., Henry, J. D., Trollor, J. N., Lammel, A., Ames, D., … Sachdev, P. S. (2012). Genetic influences on five measures of processing speed and their covariation with general cognitive ability in the elderly: The older Australian twins study. Behavior Genetics, 42(1), 96–106. doi:10,1007/s10519-011-9474-1

Llewellyn, D. J., Lang, I. A., Langa, K. M., & Huppert, F. A. (2008). Cognitive function and psychological well-being: findings from a population-based cohort. Age and Ageing, 37(6), 685–689. doi:10.1093/ageing/afn194

McGrew, K. S., & Evans, J. J. (2004). Internal and external factorial extensions to the Cattell–Horn–Carroll (CHC) theory of cognitive abilities: A review of factor analytic research since Carroll's Seminal 1993 Treatises. St. Cloud, MN: Institute for Applied Psychometrics.

Miller, J. O., & Low, K. (2001). Motor Processes in Simple, Go/No-Go, and Choice Reaction Time Tasks: A Psychophysiological Analysis. Journal of Experimental Psychology. Human Perception and Performance, 27(2), 266–289. doi:10,1037/0096-1523.27.2.266

Miller, D. C. (2013). Essentials of school neuropsychological assessment (2nd ed.). Hoboken, NJ: John Wiley & Sons, Inc.

Mitchinson, A. R., Kim, H. M., Geisser, M., Rosenberg, J. M., & Hinshaw, D. B. (2008). Social Connectedness and Patient Recovery after Major Operations. Journal of the American College of Surgeons, 206(2), 292–300, doi:10,1016/j.jamcollsurg.2007.08.017

Mueller, S. T., & Piper, B. J. (2014). The Psychology Experiment Building Language (PEBL) and PEBL Test Battery. Journal of Neuroscience Methods, 222, 250-259. doi:10,1016/j.jneumeth.2013.10,024.

Mueller, S. T. (2010). A Partial Implementation of the Bica Cognitive Decathlon Using the Psychology Experiment Building Language (Pebl). International Journal of Machine Consciousness, 02(02), 273–288. doi:10,1142/S1793843010000497.

Pakalniškienė V. (2013). Tyrimo ir įvertinimo priemonių patikimumo ir validumo nustatytmas. Vilnius: Vilniaus universiteto leidykla.

Piek, J. P., Dawson, L., Smith, L. M., & Gasson, N. (2008). The role of early fine and gross motor development on later motor and cognitive ability. Human Movement Science, 27(5), 668–681. doi:10,1016/j.humov.2007.11.002

Rady, A., Elsheshai, A., Abou el Wafa, H., & Elkholy, O. (2012). WCST Performance in Schizophrenia and Severe Depression with Psychotic Features. ISRN Psychiatry, 2012, 1–4. doi:10,5402/2012/373748

Rohde, T. E., & Thompson, L. A. (2007). Predicting academic achievement with cognitive ability. Intelligence, 35(1), 83–92. doi:10,1016/j.intell.2006.05.004

Salami, A., Eriksson, J., Nilsson, L.-G., & Nyberg, L. (2012). Age-related white matter microstructural differences partly mediate age-related decline in processing speed but not cognition. Biochimica et Biophysica Acta, 1822(3), 408–415. doi:10,1016/j.bbadis.2011.09.001.

Salthouse, T. A. (1992). Influence of processing speed on adult age differences in working memory. Acta Psychologica, 79(2), 155–170, doi:10,1016/0001-6918(92)90030-h

Salthouse, T. A. (1993). Speed mediation of adult age differences in cognition. Developmental Psychology, 29(4), 722–738. doi: 10,1037/0012-1649.29.4.722

Salthouse, T. A. (1996). The Processing-Speed Theory of Adult Age Differences in Cognition, Psychological Review, 103(3), 403-428. doi:10,1037/0033-295X.103.3.403.

Salthouse, T. (2000). Aging and measures of processing speed. Biological Psychology, 54, 35-54. doi: 10,1016/s0301(-0511(00)00052-1.

St Clair-Thompson, H. L., & Allen, R. J. (2013). Are forward and backward recall the same? A dual-task study of digit recall. Memory & Cognition, 41(4), 519–32. doi:10,3758/s13421(-012(-0277-2

Stern, Y. (2009). Cognitive reserve. Neuropsychologia, 47(10), 2015–2028. doi:10,1016/j.neuropsychologia.2009.03.004

Surkevičiūtė, M. (2016). Regimosios erdvinės ir žodinės atminties bei vykdomųjų funkcijų sąsajos (Bakalauro darbas). Vilnius: Vilniaus universitetas.

Tabachnick, B. G., & Fidell, L. S. (2013). Using Multivariate Statistics (6th ed., pp. 1–983). New Jersey: Pearson Education Inc.

Wagenmakers, E.-J., Ratcliff, R., Gomez, P., & McKoon, G. (2008). A Diffusion Model Account of Criterion Shifts in the Lexical Decision Task. Journal of Memory and Language, 58(1), 140–159. doi:10,1016/j.jml.2007.04.006.

Westerberg, H., & Klingberg, T. (2007). Changes in cortical activity after training of working memory - a single-subject analysis. Physiology and Behavior, 92(1-2), 186–192. doi: 10,1016/j.physbeh.2007.05.041

World Health Organization. Neurological Disorders: Public Health Challenges. Geneva: World Health Organization, 2006. Iš http://www.who.int/mental_health/neurology/neurological_disorders_report_web.pdf

Witt, S. T., Laird, A. R., & Meyerand, M. E. (2008). Functional neuroimaging correlates of finger-tapping task variations: an ALE meta-analysis. Neuroimage, 42(1), 343-356. doi: 10,1016/j.neuroimage.2008.04.025

Wittchen, H. U., Jacobi, F., Rehm, J., Gustavsson, a, Svensson, M., Jönsson, B., … Steinhausen, H.-C. (2011). The size and burden of mental disorders and other disorders of the brain in Europe 2010, European Neuropsychopharmacology : The Journal of the European College of Neuropsychopharmacology, 21(9), 655–79. doi:10,1016/j.euroneuro.2011.07.018

Žliobaitė, R. (2016). Amžiaus sąsajos su paprastos ir sudėtingos informacijos apdorojimo greičiu ir verbaline bei vaizdine atmintimi (Bakalauro darbas). Vilnius: Vilniaus universitetas.

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Publications in scientific journals

Jurkuvėnas, V. (2015). Amžiaus sąsajos su paprastos ir sudėtingos informacijos apdorojimo greičiu, atmintimi bei psichinės veiklos perkėlimu [Relations Among Age, Simple Information Processing Speed, Complex Information Processing Speed, Memory, and Set-Shifting]. *Psichologija*, 51(51), 81. doi:10.15388/psichol.2015.51.8258

Jurkuvėnas, V., Bagdonas, A., & Germanavičius, A. (2016). Simple and Complex Information Processing Speed in Psychiatric Samples [Psichikos sveikatos sutrikimų turinčių asmenų paprastos ir sudėtingos informacijos apdorojimo greitis]. *Psichologija*, 53(53), 7. doi:10.15388/psichol.2016.53.10029

Presentations at international conferences

Jurkuvėnas V. (2015) *Measures of Wisconsin Card Sorting Test performance in adult psychiatric inpatients and healthy subjects*. In M. Tummino, M. Bollati, & A. Widmann (Eds.), Linking technology and psychology: feeding the mind, energy for life. Abstract book, 1531. The 14th European Congress of Psychology, Milan, Italy.

Jurkuvėnas V., Bagdonas A. (2016) Age and processing speed as predictors of different executive function task performance. The 24th Biennial Meeting of the International Society for the Study of Behavioural.

Jurkuvėnas V., Bagdonas A. (2016) Age and other predictors of simple and complex processing speed. The 24th Biennial Meeting of the International Society for the Study of Behavioural.

Presentations at national conferences

Jurkuvėnas V. (2015) Kas geriau prognozuoja pažintinį funkcionavimą: psichosocialiniai veiksniai ar amžius? Lietuvos psichologų kongresas.

Jurkuvėnas, V., Girdzijauskienė, S., Zamalijeva, O. (2015). Trajectories of Cognitive Aging: Findings from Adult Cognition Studies. 7th Conference of Lithuanian Neuroscience Association, Vilnius, Lithuania. Abstract booklet (p. 7). Vilnius: Vilniaus universiteto leidykla.