

## SIMPLE AND COMPLEX INFORMATION PROCESSING SPEED IN PSYCHIATRIC SAMPLES

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*General information processing speed (IPS) impairment is a feature of many clinical conditions. Biological underpinnings of this impairment are being explored extensively. However, less attention has been paid to the fact that simple and complex IPS impairment might be analysed separately. The overall purpose of this paper was to analyse the role of simple and complex IPS in mental disorders. Three clinical groups were compared to healthy controls (N = 381): persons with self-reported history of mental disorder (N = 33), persons being treated for mild-moderate (F10-F99, except F20-F29) mental disorder (N = 35), and persons who were being treated for severe (F20-F29) mental disorder (N = 33). Neuropsychological battery of eleven computer administered tasks was used in order to measure simple IPS, complex IPS, memory, and set-shifting. Additionally, health-related and demographic information was collected. Participants in clinical groups reported poorer health on all measured variables, especially the group of persons who were being treated for severe mental disorder. ANOVA tests indicated that there were significant differences between compared groups on all cognitive domains. These differences were most pronounced in simple and complex IPS domains. Evidence is also provided that these differences are not due to demographic features of the sample, or even inter-correlations with memory and set-shifting abilities. Furthermore, a pattern of proportions of clinically significant cognitive deficits in mixed clinical sample (N = 101) versus control group of simple IPS and complex IPS suggests that measuring these cognitive domains might be beneficial both in research and in clinical practice.*

**Key words:** simple information processing speed, complex information processing speed, memory, set-shifting, mental disorders.

Ability to process information not only accurately but also swiftly has great evolutionary advantages not only for humans but for all living beings. Rapid nerve conduction which was acquired in most vertebrates through myelination allowed both rapid reaction to available prey and ability to escape sudden predatory attacks (Zalc & Colman, 2000). IPS (Information processing speed) is thought to be one of the most basic operations of the human mind and essential both for higher cognitive abilities and in everyday living (DeLuca, 2008). The importance of studying individual difference in IPS was emphasized by Wilhelm Wundt, Sir Francis Galton, and James Mckenn Cattell during the late 1800s and early 1900s. However, due to general decline in IPS research up until late nineteenth century only during the past decades IPS changes in clinical populations began to be understood (O'Brien & Tulskey, 2008).

Although, without a doubt, psychiatric disorders are etiologically and clinically extremely heterogeneous, statistically worse performance on almost any cognitive test is a feature in most clinical samples (Gavett, 2015). General slowing of information processing is also related to psychiatric disorders, such as depression (Reppermund et al., 2007; Tsourtos, Thompson, & Stough, 2002), schizophrenia (Brebion et al., 2015; Cella & Wykes, 2013), schizoaffective disorder (Fryar-Williams & Strobel, 2015; Simonsen et al., 2011) and others. These relatively consistent findings of IPS group differences between healthy controls and mental illness could contribute to more general investigations of mechanisms underlying individual differences in IPS.

One of the most important cognitive theories about IPS came from the studies

of age-related cognitive slowing. The theory of adult age differences in cognition (Salthouse, 1996) postulated that the age changes in speed at which mental operations are performed is the leading indicator of cognitive aging. Salthouse (1996) argued that most fluid abilities depend on IPS through execution speed of relevant operations and availability of early processing products in later processing. This theory has subsequently been supported by many investigators using various methodological approaches (Coyle, Pillow, Snyder, & Kochunov, 2011; Finkel, Reynolds, McArdle, & Pedersen, 2005; Fry & Hale, 1996). On the other hand, it is not clear if this theory applies to cognitive deficits not related to aging. Also, conceptualising IPS as a mediator between age and other cognitive abilities does not explain IPS deficits themselves, so, during the last few decades, considerable interest has been focused on biological underpinning of IPS.

A variety of neural markers have been related to IPS. It has been demonstrated that acetylcholinergic (Thompson, Stough, Ames, Ritchie, & Nathan, 2000), dopaminergic (Backman et al., 2000), and serotonergic (Herrera-Guzmán et al., 2009) neurotransmission; posterior EEG measures (Gazzaley et al., 2008) and BOLD variability between cognitive states (Garrett, Kovacevic, McIntosh, & Grady, 2013); regional brain volumes (e.g., thalamic volume (Van Der Werf et al., 2001), and even overall anatomical feature of the brain (e.g., grey matter volume and ventricular size (Coffey et al., 2001)) are all linked to information processing slowing. Also, some of the most consistent results come from studies of IPS relationship with the white matter structure (Kerchner et al., 2012)

and volume (Magistro et al., 2015). It has been shown that in mental disorders, such as schizophrenia (Antonova et al., 2005), and depression (Lesser, Boone, Mehringer, & Wohl, 1996) white matter disintegration is related to IPS. This similarity of cognitive deficits despite heterogeneity of conditions might be explained by common genetic determinants of processing speed decreasing in aging and in many brain disorders, which are mediated by structural white matter changes (Kochunov et al., 2016; Posthuma, De Geus, & Boomsma, 2001). So, now we are beginning to understand that the same biological processes that enabled quick and efficient information processing in vertebrates, lead to possibility of more complex disorders, such as psychiatric illness (Nave, 2010).

On the other hand, despite growing knowledge about the nervous system changes that are related to IPS, there are still important theoretical issues concerning this cognitive domain. First of all, it has been suggested that IPS might not be a unitary construct (Chiaravalloti, Christodoulou, Demaree, & DeLuca, 2003; Jurkuvėnas, 2015). Secondly, there is evidence to indicate that IPS tasks of different complexity show different patterns of deficit at least in some clinical samples (Gerritsen, Berg, Deelman, Visser-Keizer, & Meyboom-de Jong, 2003; Gualtieri & Johnson, 2006).

These issues might arise due to a broad definition of IPS. IPS is defined as the time required to execute a cognitive task or the amount of work that can be completed within a finite period of time (DeLuca, 2008). This amounts to a great variety of measures that can be defined as measuring IPS: from the psychomotor finger tapping

test to the speed of performing very complex attentional or executive speeded tasks. Although, it has been shown that to a large extent, processing speed measures are related despite the differences, it also has been shown that in studies investigating relationships between measures, simple and complex IPS factors emerge. Simple IPS refers to the speed of basic perceptual judgement and complex IPS involves speeded higher-order cognitive processes (Chiaravalloti et al., 2003).

Various cognitive mechanisms have been proposed in order to explain this phenomenon. It has been suggested that it is complex IPS, not simple IPS, that is closely associated with higher cognitive function (DeLuca, 2008). Hence, it has been also proposed that executive control (task switching, inhibition, and working memory) and complex IPS are, in fact, virtually one and the same cognitive domain (Cepeda, Blackwell, & Munakata, 2013). Further critique of complex IPS domain was suggested regarding its relationship with general fluid abilities, arguing that complex speed tasks tax working memory system and therefore, working memory capacity is the underlying factor rather than speed (Conway, Cowan, Bunting, Theriault, & Minkoff, 2002). Also, there seems to be evidence that at least in ADHD working memory and not processing, speed mediates fluid intelligence deficits associated with symptoms of the disorder (Brydges, Ozolnieks, & Roberts, 2015). Based on this line of research, cognitive models are now being created (DeLuca, 2008), so it is clear that the effect of non-speeded memory and executive (such as set-shifting) influences to IPS should be studied.

Despite criticism, studies in neuropsychological assessment seem to suggest that IPS might be a fundamental cognitive domain, its decline in clinical groups is separable from memory or executive domains, and that simple and complex IPS are both clinically relevant measures. Importance of both simple and complex IPS tasks in differentiating mild cognitive impairment and Alzheimer's disease (Gorus, De Raedt, Lambert, Lemper, & Mets, 2008) unilateral stroke patients (Gerritsen et al., 2003), ADHD, post-concussion syndrome and depression (Gualtieri & Johnson, 2006) has been demonstrated. However, studies about clinically significant as opposed to statistically significant differences in mental disorders are still lacking. Also, as the literature suggests (Lennertz et al., 2015), sampling procedures might be important in these investigations as hospitalized samples might overestimate cognitive deficits. Furthermore, due to the psychometric nature of IPS tasks, other confounding variables, such as gender, age, education, and native language (Ruff & Parker, 1993; Salthouse, 1996; Wagenmakers, Ratcliff, Gomez, & McKoon, 2008) should be analysed before drawing conclusions about the importance of IPS in psychiatric samples.

The main goal of this study was to analyse the role of simple and complex IPS in mental disorders. This was done by comparing simple IPS, complex IPS, memory and set-shifting abilities in a group with a history of mental health problems, a group being treated for mild-moderate mental disorders, and a group being treated for severe mental disorders as well as the control group. Secondary aims of this study were to analyse group differences when adjusting for gender, age, education,

and native language; analyse group differences on simple and complex IPS when adjusting for memory and set-shifting; and to evaluate not only statistically significant group differences but also clinically significant deficits both in mixed clinical sample and healthy adults.

## Method

**Participants.** Part of this data was previously published (Jurkuvėnas, 2015). The previously used dataset of 415 participants was expanded to 520 participants. However, participants with neurological disorders were excluded, so the final sample was composed of 482 subjects. Study sample was a convenience sample. Overall, the sample was mostly comprised of women (63.9 %), median age was 30, median years of education was 15, they were Lithuanian native speakers (84.0 %), working (51.0 %) and single (not married and doesn't live with a partner, 40.9%). 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. The first clinical sample – the Mental health problems History Group (MHG) (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 – the Mild-moderate mental disorder Treatment Group (MTG) (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 centre during testing, all of these patients were having psychopharmacological treatment. So sampling procedure was different between MHG and MTG. Most of the participants in the MTG were diagnosed with depression (F32). The third clinical sample – the Severe mental disorder Treatment

Group (STG) (N = 33) was comprised of individuals who were diagnosed with severe (F20-F29) mental disorder who were treated in mental health centre, all of these patients were also having psychopharmacological treatment and were much less likely to receive psychotherapeutic treatment than the MTG. Most of the participants in this group were diagnosed with paranoid schizophrenia (F20.0).

Descriptive statistics of these groups, including demographic and health variables, are presented in Table 1 and Table 2. The groups did not differ in age, years of education or gender proportion. There were significant differences on subjective physical health (6-point Likert scale), subjective

*Table 1. ANOVA group comparisons on age, years of education, and health variables (means (SD))*

Variables	CG	MHG	MTG	STG
Age	33.16 (12.81)	35.85 (14.03)	37.43 (13.62)	35.33 (10.19)
<b>F = 1.692 df = 3 p = 0.168 <math>\eta^2 = 0,01</math></b>				
Years of education	14.91 (4.02)	14.24 (3.47)	14.61 (3.29)	14.85 (4.07)
<b>F = 0.313 df = 3 p = 0.816 <math>\eta^2 = 0,00</math></b>				
Subjective physical health	4.69 (0.99) <sup>MTG STG</sup>	4.06 (1.39)	3.77 (1.35) <sup>CG</sup>	3.55 (1.50) <sup>CG</sup>
<b>F = 19.128 df = 3 p &lt; 0.010 <math>\eta^2 = 0,11</math></b>				
Subjective mental health	4.86 (0.89) <sup>MHG MTG STG</sup>	3.64 (1.08) <sup>CG</sup>	3.03 (1.15) <sup>CG</sup>	3.39 (1.64) <sup>CG</sup>
<b>F = 64.257 df = 3 p &lt; 0.010 <math>\eta^2 = 0,29</math></b>				
Number of working days lost to sickness absence	4.65 (17.21) <sup>MTG STG</sup>	11.70 (19.88)	16.34 (22.59) <sup>CG</sup>	41.36 (48.22) <sup>CG</sup>
<b>F = 32.141 df = 3 p &lt; 0.010 <math>\eta^2 = 0,17</math></b>				
Body-mass index	23.77 (4.21) <sup>STG</sup>	23.46 (4.86) <sup>STG</sup>	24.47 (4.03) <sup>STG</sup>	28.08 (6.23) <sup>CG MHG MTG</sup>
<b>F = 9.979 df = 3 p &lt; 0.010 <math>\eta^2 = 0,06</math></b>				

*Notes:* CG – Control Group, MHG – Mental health problems History Group, MTG – Mild-moderate mental disorder Treatment Group, STG – Severe mental disorder Treatment Group, significant differences are presented in bold, partial  $\eta^2$  – effect size indicated by partial eta squared. Post-hoc comparison significant differences are presented in superscript.

**Table 2. Chi-square group comparisons on gender, native language, occupational status and family status (n(%))**

Variables	N	CG	MHG	MTG	STG
<b>Gender</b>					
Male	201	138 (36.2)	5 (15.2)	17 (48.6)	14 (42.4)
Female	355	243 (63.8)	28 (84.8)	18 (51.4)	19 (57.6)
<b><math>\chi^2 = 9.21</math> df = 3 p = 0.027</b>					
<b>Native language</b>					
Lithuanian	474	329 (86.6)	24 (72.7)	25 (73.5)	27 (81.8)
Russian	53	33 (8.7)	8 (24.2)	3 (8.8)	6 (18.2)
Polish	26	18 (4.7)	1 (3.0)	6 (17.6)	0
<b><math>\chi^2 = 22.674</math> df = 6 p = 0.001</b>					
<b>Occupational status</b>					
Work	279	206 (54.1)	17 (51.5)	12 (34.3)	11 (33.3)
Study	114	88 (23.1)	6 (18.2)	3 (8.6)	2 (6.1)
Work and study	98	71 (18.6)	5 (15.2)	1 (2.9)	0
Unemployed	65	16 (4.2)	5 (15.2)	19 (54.3)	20 (60.6)
<b><math>\chi^2 = 154.209</math> df = 9 p &lt; 0.011</b>					
<b>Family status</b>					
Married	186	140 (36.7)	7 (21.2)	9 (25.7)	4 (12.1)
Single	230	151 (39.6)	11 (33.3)	17 (48.6)	18 (54.5)
Living with significant other	73	51 (13.4)	9 (27.3)	3 (8.6)	0
Divorced	50	27 (7.1)	5 (15.2)	4 (11.4)	10 (30.3)
Widowed	17	12 (3.1)	1 (3.0)	2 (5.7)	1 (3.0)
<b><math>\chi^2 = 39.659</math> df = 12 p &lt; 0.011</b>					

Notes: CG – Control Group. MHG – Mental health problems History Group. MTG – Mild-moderate mental disorder Treatment Group. STG – Severe mental disorder Treatment Group. Significant differences are presented in bold.

mental health (6-point Likert scale), number of working days lost to sickness, absence and body-mass index, which indicates validity of sampling procedure. Also, there were significant differences on native language, occupational status and family status.

**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. The same neuropsychological test battery was used as in the previous research (Jurkuvėnas, 2015). Overall par-

ticipants completed eleven PEBL (The Psychology Experiment Building Language) open source software (Mueller, 2010; Mueller & Piper, 2014) based computer administered tasks.

A researcher was present throughout testing to answer any questions. Testing was performed using Windows XP, 7, 8 or 10 software, using resolution of 800 × 600 (responses were made using a mouse and a keyboard). Each test, except the Yes/No recognition test and the Berg “Wisconsin” Card Sorting Test, had a practice phase.

*Rotor pursuit task (RPT)*. This is a sensorimotor 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. There are 3 15-second trials. RPT score was the mean time on target.

*Finger tapping test (FTT)*. This 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 response time (CRT)*. This 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. CRT score is the mean reaction time.

*Lexical decision task (LDT)*. This task measures lexical retrieval speed (Wagenmakers et al., 2008). Participants have to respond as quickly and accurately as possible to a visually-displayed words or non-words (misspelled words), by pressing the right key if a word is written correctly and left key if it is not a word. LDT score is the mean reaction time.

*Semantic categorisation task (SCT)*. This task 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. Overall, 7 categories are presented. SCT score is the mean reaction time.

*Object judgement task (OJT)*. The test 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. OJT score is a measure of response efficiency (the mean reaction time divided by proportion of correct responses in the study).

*The Tower of London (TOL)*. The move time measure of this classical executive function test was used to measure the planning speed (Kremen et al., 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. TOL score is the mean move time.

*Forward digit span (FDS)*. This test 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)*. This test 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)*. This 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. YNR score is the number of correct responses.

*Berg "Wisconsin" Card Sorting Test (BCST)*. This task 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 categorise 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 categorisation (BCST-u).

Simple IPS was measured using RPT, FTT and CRT, complex IPS was measured using LDT, SCT, OJT and TOL task, memory domain was comprised of FDS, CST, YNR, and set-shifting ability was composed of BCST-c and BCST-u measures. 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 ( $\chi^2 = 135.926$ ;  $df = 47$ ;  $p < 0.001$ ; RMSEA = 0.063; CFI = 0.950; TLI = 0.930) very similar to those reported previously (Jurkuvėnas, 2015). Test-retest reliability of these composite scores in student sample is satisfactory for set-shifting and high for memory, simple and complex IPS (Jurkuvėnas, 2015).

**Statistical Analyses.** Our approach to analysing group differences in cognitive abilities was to create composite scores for both simple and complex IPS tests and for memory and set-shifting test domains. This was advantageous because it reduced the number of dependent variables, improved the robustness of the underlying cognitive construct, gave better reliability with multiple measures per construct and lowered probability of analyses/family-wise error rate (Jones et al., 2014; Schiepers et al., 2009). Composite score for each domain was calculated by summing up z scores of individual tests. Each composite score was also transformed into z score so that higher values reflect better performance.

In order to analyse differences between groups on demographic and health variables, we used analysis of variance (ANOVA) to compare the mean age, years of education, subjective physical health, subjective mental health, number of working days lost to sickness absence, and body-mass index. Also,  $\chi^2$  test was used to compare proportions of gender, native language, occupational status, and family status between controls and clinical groups.

Neuropsychological test composite score intergroup differences were analysed using ANOVA followed by Games-Howell (due to heterogeneity of variances) multiple comparison tests. We also used ANCOVA to adjust for possibly confounding variables. Standardised scores were used in order to enable estimation of clinical differences. We co-varied for age and education in first ANCOVA analyses to adjust for these cofounders and we performed second ANCOVA for group differences in simple and complex IPS adjusting for memory and set-shifting.

The frequency of abnormal test results were calculated separately for the control and clinical samples. We used common thresholds that are used in neuropsychology for identifying abnormal scores: 1, 1.5 and 2 standard deviations below the mean (Gavett, 2015). The relationships between variables were tested using  $\chi^2$  statistic.

## Results

The aim of this study was to examine the aspects of simple and complex IPS in population based and inpatient clinical samples and to compare simple and complex IPS deficits in clinical samples with those of memory and set-shifting ability. Figure 1 displays means and standard errors of each clinical group and control group,

according to cognitive abilities domain. ANOVA tests (Table 3) showed that there were significant differences between compared groups on all cognitive domains. Post-hoc analysis indicated significant differences between CG compared to STG on all four cognitive domains; CG compared to MTG on complex IPS; MHG compared to STG on complex IPS, memory and set-shifting; and MTG compared to STG on set-shifting.

In order to analyse gender, age, years of education, and native language as possible confounding variables, we conducted ANCOVA test adjusting for age and education only for the group of female Lithuanian native speakers (CG – N = 209; MHG – N = 21; MTG – N = 12; STG – N = 14). No changes were found in terms of statistical significance or direction of effect compared to all sample ANOVA analysis. However, it is important to note that the effect size increased in simple IPS, and decreased in complex IPS domains: simple IPS – F(3) = 8.79,  $p < 0.01$ , partial  $\eta^2 = 0.10$ ; complex IPS – F(3) = 3.54,  $p = 0.02$ , partial  $\eta^2 = 0.04$ ; memory – F(4) = 4.61,  $p < 0.01$ , partial  $\eta^2 = 0.05$ ; set-shifting – F(4) = 5.60,  $p < 0.01$ , partial  $\eta^2 = 0.06$ .

To investigate memory and set-shifting domains as possible confounding variables for group differences in simple and complex IPS, we conducted ANCOVA test adjusting memory and set-shifting domains. Again, no changes were found in terms of statistical significance or direction of effect compared to all sample ANOVA analysis. On the other hand, it is important to note that effect sizes decreased for both simple IPS – F(3) = 6.69,  $p < 0.01$ , partial  $\eta^2 = 0.04$ , and complex IPS – F(3) = 5.27,  $p < 0.01$ , partial  $\eta^2 = 0.03$ .

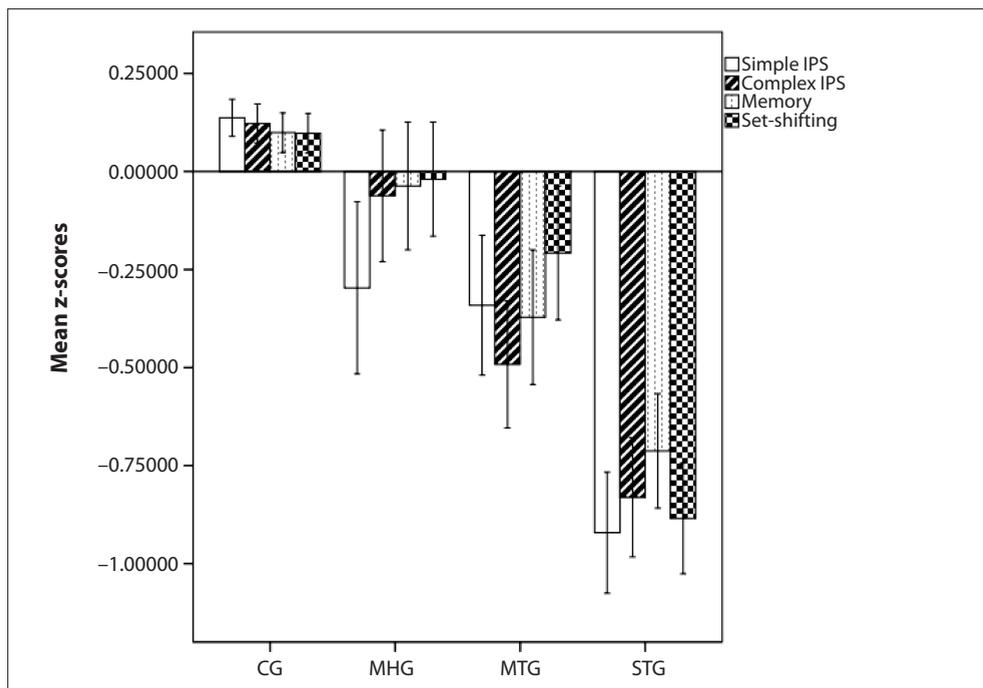


Figure 1. The means and standard errors of each clinical group and control group, according to cognitive abilities domain. CG – Control Group, MHG – Mental health problems History Group, MTG – Mild-moderate mental disorder Treatment Group, STG – Severe mental disorder Treatment Group

Table 3. ANOVA and Post-hoc test results for group differences on four cognitive domains

Variables	ANOVA test	Post-hoc (* < 0.05 ** < 0.01)
Simple IPS	F = 15.291 df = 3 p < 0.011 partial $\eta^2$ = 0.09	CG-STG**
Complex IPS	F = 13.317 df = 3 p < 0.011 partial $\eta^2$ = 0.08	CG-MTG* CG-STG** MHG-STG**
Memory	F = 8.871 df = 3 p < 0.011 partial $\eta^2$ = 0.05	CG-STG** MHG-STG*
Set-shifting	F = 10.962 df = 3 p < 0.011 partial $\eta^2$ = 0.06	CG-STG** MHG-STG** MTG-STG*

Notes: CG – Control Group, MHG – Mental health problems History Group, MTG – Mild-moderate mental disorder Treatment Group, STG – Severe mental disorder Treatment Group, \* p < 0.05, \*\* p < 0.01, partial  $\eta^2$  – effect size indicated by partial eta squared.

Lastly, we investigated the proportion of clinically significant deficits in mixed clinical sample and control group. In total, 292 subjects (60.6 %) did not have clinically significant deficits (< 1SD) in any of four composite scores, 104 (21.6 %) had

one clinically significant result, 54 (11.2%) had two abnormal results, 23 (4.8%) had three and 9 (1.9 %) had all four. Before analysing proportions of clinically significant results, we performed Student’s t test to confirm statistical significance in

Table 4. Percentage of abnormal test results based on cognitive domain, group and cut-off score

Variables	Control group (N = 381)			Mixed clinical group (N = 101)		
	% 1SD	% 1.5 SD	% 2 SD	% 1SD	% 1.5 SD	% 2 SD
Simple IPS	11.5	4.7	2.4	31.7	15.8	10.9
Complex IPS	13.4	5.0	1.8	32.7	15.8	5.9
Memory	11.0	3.7	1.8	22.8	12.9	6.9
Set-shifting	15.7	7.6	1.0	31.7	10.9	3.0

the overall mixed sample versus control sample differences in cognition. Two groups were different in all cognitive domains: Simple IPS (MCS – M = –0.52 SD = 1.10; CG – M = 0.14 SD = 0.92)  $t(480) = 6.047$   $p < 0.01$ ; Complex IPS (MCS – M = –0.46 SD = 0.98; CG – M = 0.12 SD = 0.97)  $t(480) = 5.374$   $p < 0.01$ ; Memory (MCS – M = –0.37 SD = 0.96; CG – M = 0.10 SD = 0.97)  $t(480) = 4.300$   $p < 0.01$ ; Set-shifting (MCS – M = –0.37 SD = 0.96; CG – M = 0.10 SD = 0.99)  $t(480) = 4.226$   $p < 0.01$ .

We analysed the percentage of abnormal test results based on cognitive domain, group and cut-off score. These results are shown in Table 4. Lower proportion of abnormal scores was, as expected, related to the cut-off score. Also, the mixed clinical sample (measured with  $\chi^2$  test,  $p < 0.05$ ) had significantly more abnormal test results compared to the normal sample in all except the set-shifting domain at 1.5 SD ( $p = 0.31$ ) and 2 SD cut-off ( $p = 0.16$ ). The largest percentage in mixed clinical sample of abnormal (1 SD cut-off) results was in the complex processing speed domain and the lowest was for memory domain. The smallest percentage of abnormal results (1 SD cut-off) in control group was in memory domain and the highest in set-shifting.

## Discussion

The main purpose of this study was to investigate the role of simple and complex information processing speed (IPS) in mental disorders. The findings indicate differences between compared groups not only on simple and complex IPS but also in memory and set-shifting domains. This general comparison seems to replicate the findings of most neuropsychological studies suggesting general cognitive deficits in most brain disorders when analysing mixed samples (Gavett, 2015). Furthermore, the effect sizes were greatest for simple and complex IPS, which leads to believe that simple IPS and complex IPS, at least in general comparisons, are useful indicators of cognitive decline in mental disorders.

However, the patterns of differences were not consistent, there were no significant differences in post-hoc analysis between the control group (CG) and a group with a history of mental health problems (MHG) in any of the four cognitive domains. Also, a group being treated for a mild to moderate mental disorder (MTG) performed worse than CG only in the complex IPS domain. So, these comparisons revealed that the performance decline consistency across all cognitive domains is present only in a group being treated for severe mental disorders (STG). These

results are partially in keeping with those showing overestimation of cognitive deficits in persons that are currently being treated (Lennertz et al., 2015). On the other hand, these mixed significant and non-significant results might be affected by sample sizes and heterogeneity of disorders.

Covariate analysis for the group of females natively speaking Lithuanian adjusting for age and years of education indicated that simple IPS deficits might be underrepresented and complex IPS underrepresented due to demographic features in the samples. It has been shown that simple IPS might be sensitive to gender differences in the groups due to psychomotor nature of these tasks (Ruff & Parker, 1993), and complex IPS might overestimate deficits in groups which are composed of less natively speaking the language the test is in because two of four measures included in the complex IPS composite score are verbal speed measures (Wagenmakers et al., 2008). However, it is important to note, that changes in effect sizes for simple and complex IPS did not affect significance of group differences. Furthermore, by comparing only females natively speaking Lithuanian, we even further reduced the group sample sizes which leads to difficulties in result interpretability.

Also, it is important to note that group differences on subjective physical health, subjective mental health, number of working days lost to sickness absence, body-mass index, occupational status, and family status were present. This was an expected result due to the types of conditions that are being studied. For example, subjective psychological and mental health is a feature of health problems and conditions across a large spectrum (Levinson, & Kaplan, 2014). However, it is must be

acknowledged that these health and socio-economic sample differences show that quite possibly it is not only condition of mental illness itself that affects cognitive decline in clinical versus control group comparisons.

Consistent with the results of previous studies suggesting that IPS is an independent cognitive domain related to mental disorder (Brebion et al., 2015; Fryar-Williams & Strobel, 2015; Reppermund et al., 2007), when adjusting for memory and set-shifting ability as possible confounding variables no changes were found in terms of statistical significance or direction of effect. Nevertheless, the effect sizes were reduced both for simple and complex IPS quite significantly, which leads to believe that cognitive domains in this study are interrelated. Of course, it is worth noting that in cross-sectional design it is practically impossible to infer which domain was the mediator and which was the independent variable. However, these findings along with group differences in ANOVA test suggests a possibility that it might be possible to expand the Salthouse (1996) theory of adult age differences in cognition to mental disorder related cognitive decline. This would mean that processing speed might be one of the leading indicators not only for aging related cognitive decline but also in mental disorder related cognitive impairment.

When all three clinical samples were aggregated and compared to controls, both simple and complex IPS showed not only statistically significant results, but these domains had greater differences (as indicated by t values) in the group comparison than both memory and set-shifting. Furthermore, we aimed to investigate the proportion of clinically significant deficits both in mixed clinical sample and healthy

adults. Patterns of proportional distribution of abnormal scores in general seem to be very similar to those acquired when analysing similar groups with other batteries (Gavett, 2015). Results reveal that the mixed clinical sample had two to three times more people who performed at the level of clinical significance.

An important result for understanding the importance of IPS measures was that complex IPS had the largest percentage of clinically significant results in the mixed clinical group at 1 SD cut-off and simple IPS had the largest at 2 SD cut-off. These results seem to suggest a slight advantage at detecting clinically significant deficits in a mixed clinical sample of both simple and complex IPS measures over memory and set-shifting domains. Indeed, research show that IPS task complexity has an effect on group differences in clinical samples (Gorus et al., 2008). In general, the comparison of mixed clinical sample and control group reveals compelling evidence for importance of both simple and complex IPS composite scores.

Because of the heterogeneity of the analysed samples and different sampling procedures, this research was limited in some important ways. Part of our clinical sample diagnoses were based on self-report and part on practitioner report. Also, treatment groups (MTG, STG) were selected in the hospital and self-report (MHG) group was selected along with control group. Additionally, due to differences in sampling, we did not collect treatment information about clinical groups, despite the selection procedure that all of the treatment group participants had psychopharmacological treatment. Also, set-shifting ability domain score was composed of two scores of the same task, which could have led to lower reliabili-

ty and validity of this composite score. Study sample could have had important health related and socioeconomic differences. Specifically, control group performance should be interpreted with caution as this group is very different on most health measures, occupational and family status, not only status of mental illness.

Granting these limitations, this study had several strengths. Particularly, we were able to perform extensive neuropsychological testing on 482 subjects and gather not only demographic but also health related information. In case of MHG group, examiners were blinded to history of mental illness. Although clinical samples were small, there were no differences on age or years of education compared to the control group and we performed an additional analysis to check if gender and native language had an effect. Furthermore, we did not use individual test scores, which often leads to problems of multiple comparisons and less reliability of the scores. Lastly, we measured not only statistical but also clinical significance in three most common cut-off scores.

Future research should build upon this and similar studies, analysing simple and complex IPS in clinical samples. First of all, more studies are needed to replicate these findings with larger and heterogeneous mental disorder samples, preferably measuring both treatment type and symptom types and severity. This could lead to findings about a possibly different simple and complex IPS relationship not only with the type of condition but also with psychopharmacological treatment types and symptom severity and types. Secondly, researcher on mental disorders should include samples that are based on equivalent sampling procedures in both control and clinical groups

in order not to overestimate cognitive deficits in mental disorders. Thirdly, presenting clinically significant cognitive underperformance is crucial for understanding differences between clinical and control groups. Finally, although very difficult, neuropsychological testing before and after treatment in mental health clinics, would allow more insights into how much of these deficits are short-term or long-term.

In summary, the findings of this study show importance of both simple and complex processing speed domains in mental disorders. Although, there were significant

differences between the compared groups on all cognitive domains, general differences were greatest in simple and complex IPS. Evidence is also provided that these differences are not due to demographic features of the sample, or even inter-correlations with memory and set-shifting abilities. Furthermore, a pattern of proportions of clinically significant cognitive deficits in the mixed clinical sample versus the control group of simple IPS and complex IPS suggests that measuring these cognitive domains might be useful both in research and in clinical practice.

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## PSIHIKOS SVEIKATOS SUTRIKIMŲ TURINČIŲ ASMENŲ PAGRASTOS IR SUDĖTINGOS INFORMACIJOS APDOROJIMO GREITIS

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### S a n t r a u k a

Informacijos apdorojimo greičio sutrikimai yra būdingas daugelio psichikos sveikatos sutrikimų elementas. Šiuo metu plačiai nagrinėjami biologiniai informacijos apdorojimo greičio mechanizmai. Kita vertus, informacijos apdorojimo greitis, kaip dvilypis konstruktas, susidedantis iš paprastos ir sudėtingos informacijos apdorojimo greičio komponentų, vis dar menkai suprastas. Šiuo tyrimu siekta atskleisti paprastos ir sudėtingos informacijos apdorojimo greitį kaip psichikos sutrikimo ženklą. Taip pat keltas uždavinys išanalizuoti grupių skirtumus pagal tokius kintamuosius kaip lytis, amžius, išsimokslinimas ir gimtoji kalba; nustatyti atminties bei psichinės veiklos perkėlimo gebėjimų įtaką paprastos ir sudėtingos informacijos apdorojimo greičio sąsajai su psichikos sutrikimais; ištirti kliniškai svarbių paprastos ir sudėtingos informacijos apdorojimo greičio sutrikimų proporcijas įvairialypėje klinikinėje ir kontrolinėje grupėse. Tyrime iš viso dalyvavo 482 asmenys. Tirtos keturios grupės: sveikų suaugusiųjų (N = 381), asmenų, savistatos būdu nurodžiusių psichikos sveikatos sutrikimo diagnozę (N = 33), asmenų, kuriems diagnozuotas lengvas ar vidutinio sunkumo psichikos sveikatos sutrikimas (F10-F99, išskyrus F20-F29) (N = 35), asmenų, kuriems dia-

gnozuotas sunkus psichikos sveikatos sutrikimas (F20-F29) (N = 33). Visi tyrimo dalyviai, naudodamiesi kompiuteriu, atliko vienuolika pažintinėms funkcijoms tirti skirtų užduočių, atsakė į demografinius ir su sveikata susijusius klausimus. Gauti rezultatai atskleidžia psichikos sveikatos sutrikimų turinčiųjų ir neturinčiųjų grupių skirtumus, kurie ypač ryškūs lyginant paprastos ir sudėtingos informacijos apdorojimo greitį. Lytis, amžius, išsimokslinimas ir gimtoji kalba neturėjo įtakos tarpgrupinių pažintinių gebėjimų skirtumų statistiniam reikšmingumui. Kontroluojant atminties ir psichinės veiklos perkėlimo gebėjimus paaiškėjo, kad grupių paprastos ir sudėtingos informacijos apdorojimo greitis skyrėsi, nors sumažėjo efekto dydis. Kliniškai svarbių paprastos ir sudėtingos informacijos apdorojimo greičio sutrikimų proporcijos sudėtinėje klinikinėje grupėje ir kontrolinėje grupėje leidžia kelti prielaidas, kad paprastos ir sudėtingos informacijos apdorojimo greičio gebėjimų matavimo pritaikomumas yra skirtingas.

**Pagrindiniai žodžiai:** paprastos informacijos apdorojimo greitis, sudėtingos informacijos apdorojimo greitis, atmintis, psichinės veiklos perkėlimas, psichikos sutrikimai.