The correlation between results in different domains of cogitive abilities in medical students

Qazzafi, Aisha

UNIVERSITY OF SPLIT
SCHOOL OF MEDICINE

AISHA QAZZAFI

THE CORRELATION BETWEEN RESULTS IN DIFFERENT DOMAINS OF COGNITIVE ABILITIES IN MEDICAL STUDENTS

DIPLOMA THESIS

Academic year:
2020/2021

Mentor:
Assist. Prof. Ivana Pavlinac Dodig, MD, PhD

Split, July 2021

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

I would first like to thank my thesis supervisor Assist. Prof. Ivana Pavlinac Dodig, MD, PhD for her consistent support and exceptional mentorship. Not only do I have full appreciation for all of her guidance and encouragement throughout this research, I also admire her wonderful work ethic.

I would like to express my profound gratitude and love to my parents, Rahat and Zaman, for always supporting and motivating me. My mother's unconditional love and my father's strength have fuelled me to be the individual that I am today.

I am very grateful for my older brother, Hassan, for his constant kindness, great humour and wisdom, and for continuing to be my best friend despite me studying away from home.

Lastly, I would like to thank my close and astoundingly supportive circle of friends all over the world for their persistent warmth and company.

1. INTRODUCTION

Cognitive actions are necessary in medical students, to be able to reason clinically, such as medical decision-making and problem-solving. These cognitive actions involve identifying the problem, processing the information, creating a plan for the next step, carrying out this plan and then evaluating the results (1).

The differences in environmental and genetic factors of an individual contribute to the variation of their intelligence and cognitive abilities (2).

Genetics accounts for approximately 50 to 70% of cognition, which has been based on studies of identical and fraternal twins raised together, identical twins separated at birth and raised apart, and adoptive families (3). The influence of genetics on cognitive abilities actually increases with age (4). As we age, due to oxidative stress and inflammation induced by certain environmental factors, there is a progression in neuronal damage. This damage is repaired by certain repair processes which are genetically determined, and it is likely that these particular genes can also lead to changes in cognition due to age (2).

1.1. Intelligence

Intelligence is defined as the ability to acquire and apply knowledge and skills. It integrates cognitive functions such as perception, attention, memory, language, or planning (5). Intelligence is measured by conventional standardized tests, and varies across the lifespan, and also across generations (6).

Charles Spearman, a psychologist from the early 20th century, discovered that when students performed well in one subject, they would also perform well in other subjects, even if the tests are unrelated. There was always a positive correlation between performances on different tests, which indicates that there is an underlying factor conducting this success (7). Spearman referred to this as the general intelligence factor, *g*, which is a quantitative measurement of this entity in psychometrics.

General intelligence refers to having reasoning ability and behavioural flexibility, and is considered to be a good predictor for several components of life outcome, including academic achievement, the probability of success in professional careers, occupational attainment, job performance, social mobility, and even health and survival (8). Today, Intelligence Quotient (IQ) tests can be factor models for Spearman's work on *g* (9).

Based on various evidences from neuroimaging, the frontoparietal network is important for intelligence, but also to other cognitive functions. It has been concluded that there is a relation between perception and the fronto-parietal brain networks, and there is also an association between working memory capacity limitations and the parieto-occipital brain networks. The activity in frontal Brodmann areas 10, 45–47, parietal areas 39 and 40, and temporal area 21 also positively contribute to IQ score achievements (5).

1.1.1. Intelligence tests

General intelligence is a crucial competency of a medical student in order to progress through their studies (1). In fact, it has been demonstrated that intelligence is a major predictor of success in education and occupation (10). Intelligence can be assessed through intelligence tests, such as the Raven Advanced Progressive Matrices (APM), which measures fluid intelligence, *Gf* (11) and can predict academic potential. Fluid intelligence involves adapting to new and unfamiliar issues without relying on previously acquired knowledge. This contrasts with crystallised intelligence, *Gc*, which consists of previously acquired knowledge and skills formed out of education and habits (12).

It is assumed that intelligence tests can measure maximum intellectual performance, and an individual's IQ score is the measurement of this performance (13). Binet and Simon were among the first to develop IQ testing, as they aimed to identify intellectually challenged children at a French public school, as well as to educate them. They designed tests that assessed how the cognitive functioning of children built certain mental abilities, such as judgement, reasoning and comprehension. The most commonly used IQ test is the Wechsler Adult Intelligence Scale III (WAIS III), which measures a set of four mental abilities: processing speed, verbal comprehension, working memory and perceptual organisation (14).

The APM is a 60-item or 9-item nonverbal test encompassing abstract reasoning (15) where the participants are required to identify the missing piece of a 3×3 set of patterns. The participants utilise problem-solving skills and working memory in order to decipher which rule combination is needed for the pattern in each row or column, and the complexity of the test gradually increases with a greater demand of cognitive ability (11).

Previous research has identified a positive correlation between different domains of cognitive performance and IQ tests; implying that subjects who excel on one test would also excel on other cognitive tests. One study in Norway was conducted to investigate the correlations between results on IQ test and the MATRICS Consensus Cognitive Battery (MCCB), which revealed positive and significant associations between IQ and domains assessed with MCCB. This relationship was especially strong for these domains: Speed of Processing, Working Memory, and Visual and Verbal Learning (16). Another battery test exists, known as the Complex Reactionmeter Drenovac (CRD), which is a computer-generated test measuring cognitive and psychomotor performance. It is comprised of the software, four electronic instruments and provides the use of 38 standard tests (17). CRD is a chronometric instrument measuring perception, memory, psychomotor reaction, and thinking as dynamic functions of the central nervous system and attention, as well as functional disturbances. Psychomotor coordination (operative thinking) is assessed by measuring the coordinated movement of the individual's upper and lower limbs, the speed of perception can be measured by assessing the speed of light signal position discrimination (visual speed reaction time) and convergent thinking can be evaluated by measuring the speed of simple arithmetic operations of summation and subtraction (18). However, the association between IQ tests performed through the APM test and cognitive testing performed using the CRD has not yet been reported.

1.1.2. Medical school admissions tests

It can be complicated for applicants to enter into medical school due to the competition. It is perhaps equally as complicated to assess each applicant and to decide which one to accept. Several medical schools have provided selection criteria, which include aptitude tests, interviews and high scores in their previous academic careers (19). Various aptitude tests exist, such as the United Kingdom Clinical Aptitude Test (UCAT), the "Test für Medizinische Studiengänge" (TMS) in Germany (20) and the Medical College Admissions Test (MCAT) for most U.S. medical schools (21). The TMS assesses verbal-mathematical and spatial-figural abilities, and therefore includes different cognitive abilities rather than just assessing GPA alone (22). The MCAT includes four subtests; verbal reasoning, physical sciences, biological sciences and a writing sample (20), and along with undergraduate GPA, are essential components for deciding of which prospective students to accept (21). However, the UCAT gives more emphasis on cognitive abilities, whereas the MCAT is more focused on knowledge (20). The UCAT includes four cognitive sections, which assess verbal reasoning, decision-making, abstract reasoning and quantitative reasoning (19).

Cognitive aptitude tests are currently considered to be the most ideal method for selecting medical students. Assessing cognitive ability of the student is considered to be the most valuable and accurate aspect to examine, whereas assessing other aspects, such as the humanity and diligence of the student, may not be as accurate for predicting the academic success of the students. Biomedical admissions tests may be associated with good preclinical examinations results, but this is uncertain for other tests such as the Graduate Medical Schools

Admissions Test (GAMSAT) (23). However, these admissions tests are not able to predict clinical performance of the students (24).

1.1.3. Intelligence and gender

In both children and adults, the differences in intelligence between genders have been explored and are changing, as sociodemographic conditions are also evolving. This is mostly due to advances in education, employment and also gender equity. It is known that males tend to have better motor and visuospatial skills, while females are better in verbal abilities (25). Males usually also have better calculation skills, but this could be due to their more advanced spatial abilities (26). Females have better social cognitive skills as well as memory. While males do have larger crania, they specifically have a greater percentage of white matter, whereas females have a higher percentage of grey matter (27). The higher percentage of white matter demonstrates that male brains are suited for intrahemispheric communication, but the greater amount of grey matter in female brains suggests optimisation for interhemispheric communication. Males also have a greater cross-hemispheric cerebellar connectivity, and together with the intrahemispheric communication, this provides an efficient system for coordination. The interhemispheric connection in female brains permits females to outperform males on memory, attention and social cognition tests (27).

The majority of students are females at medical schools, which is likely due to the fact that more females graduate from secondary school and they often attain better grades (20). However, it has been demonstrated that there is no difference between male and female students in performance during the medical training itself (28).

1.1.4. Intelligence and nutrition

Specific nutrients have an impact on cognition by acting on cellular processes or molecular systems that are essential for maintaining cognitive function. The effects of nutrition on the brain are also linked with other lifestyle habits, such as sleep and exercise (29). It can be deduced that strategic dietary changes can be used for enhancing cognitive performance, as well as providing the brain protection from the effects of aging and damage.

There is evidence that omega-3 fatty acids provide amelioration of cognitive decline in the elderly, and might be beneficial in patients with mood disorders (29). Omega-3 increases the fluidity of neuronal membranes, and also exerts anti-apoptotic effects and maintains healthy synaptic structures. There is improved cerebral blood flow. Through these mechanisms, it has been proposed that omega-3 fatty acids could influence cognition. Omega-3 fatty acids can be found in fish, flax seeds, kiwi fruit, chia and walnuts, but modern western diets are known to be deficient in omega-3 (30).

Flavonoids (found in dark chocolate, citrus fruits and green tea) and B vitamins are also involved in improving cognitive function and preventing cognitive decline in the elderly (29). Specifically, vitamin B6, vitamin B12 and folate advance memory function in females of all ages. However, saturated fats adversely influence cognition and aggravate cognitive decline in the elderly. Saturated fats are found in meats, dairy products, coconut oil, butter, ghee – and therefore, these products as well as "junk food" reduce cognitive performance and diminish performance in learning tasks in individuals.

Certain micronutrients with antioxidant properties that are associated with mitochondrial activity also have a positive influence on cognition (29). Vitamin E is abundant in nuts, leafy green vegetables and fortified cereals. Vitamin E provides protection in memory performance in older individuals and protects synaptic membranes from oxidation, which support synaptic plasticity. Curcumin is a curry spice found in turmeric, and its antioxidant effects also seem protective for the brain, particularly against lipid peroxidation. It might be assumed that the high intake of curcumin in India contributes to the low prevalence of Alzheimer's disease in this country (29).

1.1.5. Intelligence and age

Cognitive abilities change during one's lifetime, firstly due to maturation and then later due to aging of neurons (31). The impact of age on intelligence is important to consider, given that the elderly population is increasing. Cognitive abilities can be divided into crystallised abilities and fluid abilities. Crystallised abilities can be defined as acquired knowledge from cognitive processing in the past, such as general knowledge, vocabulary and historical information. On the other hand, fluid abilities require that the individual is aware of their environment and can quickly process new information in order to problem-solve. Crystallised abilities continue to improve until around the age of 60 years, and a plateau occurs afterwards until the age of 80. However, fluid abilities demonstrate a steady decline from the age of 20 to age 80 (32).

Cognitive slowing is another feature of aging neurons, where there is a gradual deterioration of performing attentional tasks. This aggravation leads to difficulties with multitasking and attentional tasks such as grasping a telephone number when it is being quickly dictated. Consequently, cognitive slowing contributes to the higher rate of traffic accidents in the elderly population. Furthermore, word-finding becomes more demanding for older adults especially after the age 70, as they can find recalling the name of a person or a particular word more difficult (31). However, other aspects of language, such as verbal reasoning, vocabulary and speech comprehension, generally remain intact in older age. The ability to perceive spatial awareness and visuoperceptual judgement decline over time with age, whereas visual recognition of objects, shapes and designs remains intact (32).

While most aspects of memory remain stable, there are declines in new learning abilities as well as retrieval of newly learned information. Episodic memory (such as historical events and autobiographical memories) stays somewhat the same throughout life, whereas accurately identifying the source of this information grows more difficult. Memories which involve remembering how to ride a bike or how to play the piano, also known as procedural memories, do not deteriorate. In contrast, prospective memory, which includes remembering to perform a particular action in the future (such as taking medication after breakfast), often declines with advancing age.

In terms of brain structure and function, there is evidence that brain size decreases with age, given that structural brain imaging technology has demonstrated this atrophy (32). Specifically, grey and white matter volume loss occurs with age, with grey matter loss occurring predominantly in the prefrontal cortex. White matter loss occurs especially in the medial temporal lobe (including the hippocampus). With aging, there is also cortical neuron loss in particular brain regions, such as the hippocampus, substantia nigra and cerebellum. When this neuron loss is much greater, this can lead to age-related neurodegenerative diseases such as Alzheimer's Disease (AD), especially when this occurs in the entorhinal cortex and hippocampus.

There is also a loss of synapses and dysfunction of neuronal networks. This overall cognitive decline can lead to dementia, where these severe cognitive impairments can have debilitating effects on functioning in everyday life. However, certain lifestyle factors can prevent the progress of cognitive decline, which include mental stimulation, physical activity, avoiding excessive exposure to neurotoxins (such as alcohol), controlling chronic medical conditions such as diabetes, hypertension and obstructive sleep apnea and managing stress and treating depression (32).

1.1.6. Anatomical and physiological gender differences of the brain

As discussed previously, there are certain anatomical differences in the brain between the two sexes, as well as differences in brain activation. The differences in verbal and mathematical abilities mentioned earlier are likely due to cultural and educational variations, as well as stereotyping and the effects of sex hormones. However, there is evidence that females and males overall share several similarities in terms of cognitive abilities, but the largest differences exist for motor performance (33). In terms of motor tasks, throwing velocity and throwing distance are abilities which favour males. Mental rotation of 3D objects is one of the strongest cognitive sex differences, whereby males outperform females in this cognitive ability. This could be influenced by culture, as these differences disappear in individuals of a matrilineal society, but remain favouring males of a patrilineal society.

As for the influence of sex hormones, it has been concluded that different progesterone and estradiol levels affect executive functions, attention and spatial navigation. Depending on the phase of the menstrual cycle, there is variation in cerebral hemodynamics between males and females. During the low-estrogen phase, there are no differences between females and males, whereas when estrogen levels peaked, brain activation is reinforced to control cognitive task performance (33).

In terms of brain anatomy, males generally have larger volumes, but females have thicker cortices. Men are found to have approximately 6.5 times more grey matter than women, but women have 10 times the amount of white matter in their brain than men. Additionally, the cerebellum, which controls posture and balance, is found to be larger in men than in women. Given that females have a larger limbic system (which includes the hippocampus, the anterior commissure and a bundle of fibres which interconnect the two amygdalae), they are better and faster at identifying feelings than males. While this allows them to connect to others and develop bonds more easily, they are also more susceptible to suffering from depression than men. The inferior-parietal lobule is associated with mathematical ability and understanding spatial relationships, and it is significantly larger in males rather than females, which could contribute to why more males perform better at these tasks than their female counterparts (34).

1.1.7. Intelligence and education

It has been suggested that an individual’s intelligence can be heightened by pursuing an education. There is a positive association of education attainment with intelligence test scores, and it has been demonstrated that for each year of education there is an increase in intelligence test scores. Those with low intelligence during childhood could benefit significantly from education for when they are older, with an increase in intelligence test scores for each extra year of education, which would plateau after 17 years of education (35). Therefore, education provides an equalising effect for children of lower initial cognitive advantage. However, the correlation between education and intelligence could be due to more intelligent children selectively progressing further in education. Nonetheless, there is evidence that raising the school-leaving age improved IQ score, as well as indicators of health and well-being. For each year of education, only a few more IQ points are attained, which are still considered to be of great consequence at the societal level (36).

Furthermore, education does have domain-specific effects, such as improvement in memory and reasoning ability. However, education develops only certain intellectual abilities, *s* (specific ability), rather than general intelligence, *g*. Although the efficiency of cognitive operations may not be improved with education, the development of the specific cognitive domains, such as memory, can have an extensive impact on cognitive development (37).

1.1.8. Intelligence and socioeconomic status

Socioeconomic status (SES) measures one's overall position in society and their status. Thus, SES includes factors such as household income, parenting quality, education, occupation and certain family and neighbourhood characteristics, such as exposure to toxins and violence. It has been shown that SES positively correlates with intelligence and academic achievement from early childhood and through adolescence. Individuals who had low SES while growing up often encounter social and economic adversities to success and well-being, while also suffering from impaired cognition, poor health and lower emotional resilience. These effects of a low SES could be why poverty continues to persist for generations (38).

The impact of even short spells of poverty can be significantly detrimental towards the cognitive abilities and executive functions of these adults, as these individuals display lower levels of fluid intelligence and less effective problem-solving. Because of the reduced performance of executive functioning in poor individuals, it is likely that this leads to them providing less effective parenting for their children. Mothers living in poverty are more likely to practise poor habits during their pregnancy which could harm the fetus, such as smoking. They are also less likely to breastfeed their babies (39).

Furthermore, families with lower SES are more likely to experience nutritional deficiencies due to less access to healthy foods. Cognition is influenced by nutrition and caloric intake, and therefore impoverished families are likely to have lower intelligence due to the lack of healthy food. Low-SES families experience difficulties providing for the family's needs and they often live in dangerous neighbourhoods, which can trigger increased stress levels in these families. This chronic stress can impair childhood development, particularly attention control and working memory.

Childhood SES affects language processing, such as syntax, phonological awareness and vocabulary. There is evidence that children from professional families have a vocabulary range twice as wide as that of children from families on welfare. As for executive functions of working memory, it is concluded that a low SES also negatively impacts this in children. Verbal fluency and spatial working memory are also influenced by SES, and children from professional families display higher aptitudes in both of these cognitive functions (38).

1.2. Emotional intelligence

Certain factors can affect a medical student's clinical reasoning, such as their personality, critical thinking and emotional intelligence (EI) (40). Emotional intelligence is defined as the ability to perceive and express emotions, as well as to comprehend and regulate these personal and interpersonal feelings (41). There exists a classification proposed by Petrides and Furnham to distinguish EI as two distinct types; *ability EI* and *trait EI*. Ability EI involves an individual's theoretical understanding of emotions, whereas trait EI is related to behaviours during emotion-related situations, such as confronting stress or comforting an upset friend (42).

In various fields, EI is a predictor of academic achievement, life satisfaction, positive interactions with others and healthy psychological adaptation. Individuals with higher EI are more likely to understand emotions, as well as to regulate and manage them better in themselves and in other individuals (43). There is a positive correlation with lower EI and violence, delinquency and substance abuse (illegal use of alcohol and drugs) (40). According to a study performed in Sri Lanka to assess EI and academic performance, there is a relationship between higher EI and better scores on examinations. Furthermore, there is evidence that higher EI is associated with improved patient satisfaction, clinical performance, better doctor-patient relationships and improved empathy in medical consultation. Medical students and doctors with greater EI also display more competence for self-care, which allows them to be less susceptible to the stress of the medical profession itself (43).

1.3. Clinical reasoning

Knowledge alone is not sufficient to solve clinical problems, and consequently problem-solving skills are essential for becoming a clinical expert. Several cognitive abilities and different categories of knowledge are required in order to build diagnostic skills. Universities often focus their teachings on medical knowledge, which provides the student a foundation for clinical problem-solving (44). However, there are some medical schools worldwide that teach with a problem-based learning approach (PBL) (45), rather than traditional lecture-based learning with teacher-directed information to large classes (46). With PBL, there are small groups of students with a tutor facilitating the session. The tutor provides a case or scenario to the students, and cues are derived from these cases for students to define their own learning objectives. Additionally, students acquire knowledge and other desirable attributes, such as teamwork, communication skills and independent learning (45).

Diagnostic knowledge can be organised into three categories; conceptual knowledge, strategic knowledge and conditional knowledge. Conceptual knowledge is defined as the basic elements of knowledge necessary to solve certain problems, such as knowledge of specific details or terminology. Strategic knowledge includes knowledge about subject-specific skills and algorithms, and is required for executing tasks. As for conditional knowledge, this concerns knowledge about principles and generalizations and includes the interrelationships among the basic elements within a larger structure that permits them to function together (44).

Clinical reasoning is used in all patient encounters, and is a competency used for searching for and prioritising a differential diagnosis, and then deciphering the appropriate therapy and management plans. It is imperative that students have a strong knowledge base in order to build a diagnostic hypothesis generation. Enhancing a student's clinical reasoning is key to facilitating excellence in patient care (47).

1.4. Cognitive function

In simple terms, cognition refers to thinking. Cognitive function involves mental processes which gain knowledge and comprehension. These processes allow us to execute certain tasks and involve skills such as attention, language, perception, memory, motor skills, executive functions, and visual and spacing processing (48).

The neurotransmitter dopamine is involved in cognitive function (49), as well as reward and movement regulation in the brain. It is produced in the substantia nigra, ventral tegmental area and hypothalamus of the brain (50). The nerve fibres of the prefrontal cortex are rich in dopamine, especially in the outermost and deep cerebral cell layers, and therefore dopamine is involved in processing new information and effectively associating ideas. Researchers have identified at least two different receptor type families for dopamine; D-1 and D-2. The D-1 receptors are found in high concentrations in the outermost cerebral cell layers, likewise to the dopamine-containing nerve fibres. Research has also prompted that D-1 receptors are connected to efficiency in working memory (49).

Another neurotransmitter, serotonin (5-hydroxytryptamine, 5-HT) also regulates higher brain functions, such as cognition and emotional behaviour. The serotonergic system is densely distributed in the prefrontal cortex and in the hippocampus, which are the brain areas whose coordination is necessary for most cognitive functions, such as learning and memory. In the hippocampus, the serotonergic system is involved in spatial navigation, decision-making, certain memory processes and social relationships. As for the prefrontal cortex, the serotonergic system modulates working memory, reverse learning, decision-making and attention. The activity of the serotonergic system is associated with cognitive performance and short-term and long-term memory, aging and several psychiatric (alcoholism, depression, schizophrenia) and neurological (epilepsy, Alzheimer's Disease) disorders (51).

Norepinephrine (NE) is a monoamine neurotransmitter released by the locus coeruleus, and regulates synaptic transmission and cellular processes in the central nervous system and acts via α_1, α_2 and β receptors. NE plays a significant role in cognition and behaviour, such as attention, learning and memory and behavioural flexibility, as well as promoting wakefulness. Particularly, NE is necessary for memory consolidation and retrieval in the hippocampus, and is also important in the prefrontal cortex for extradimensional shifting, which is involved in behavioural flexibility. Deficits in noradrenergic signalling occurs in neurodegenerative and neuropsychiatric diseases, which is associated with the behaviour deficits and disordered cognition in these conditions, such as schizophrenia, depression, anxiety, autism, Parkinson's disease, Alzheimer's disease and attention-deficit hyperactivity disorder (ADHD) (52).

Acetylcholine (Ach), the first neurotransmitter to be identified, plays a major role in the central and peripheral nervous systems. Ach is used as a neurotransmitter for preganglionic and postganglionic parasympathetic neurons, pre-ganglionic sympathetic neurons and part of the post-ganglionic sympathetic neurons. Almost all regions of the brain are innervated by cholinergic neurons; the spinal cord, mesopontine region, hindbrain, basal forebrain, striatum, olfactory tubercle and islands of Cajella complex of the ventral striatum. The cholinergic system is essential for attention, wakefulness and sleep, learning, memory and the stress response. The use of cholinesterase inhibitors facilitates cholinergic transmission, and therefore improves attention. However, injuries to the cholinergic neurons of the basal forebrain would lead to attention deficit. Furthermore, degeneration of cholinergic neurons from the nucleus basalis of Meynert occurs in Alzheimer's Disease and is associated with the memory loss caused by this disease (53).

Gamma-aminobutyric acid (GABA) is the main inhibitory neurotransmitter in the human nervous system and its neurotransmission is used in almost all neuronal coding and processing throughout the brain. GABA influences membrane potentials via ionotropic $GABA_A$ and $GABA_C$ receptors, regulates neuronal activity through metabotropic G-protein coupled $GABA_B$ receptors, and also modifies synaptic plasticity. GABA plays a role in various brain regions for cognitive functions, such as frontal GABA concentrations are associated with working memory performance, whereas GABA concentrations in the occipital cortex are involved in visual orientation discrimination. Over time, GABA concentrations decline with age, with approximately a 5% decrease with age per decade in the frontal cortex. The frontal cortex plays a significant role in executive function, as well as other cognitive functions (54).

1.4.1. Cognitive function assessment

Classifying and characterizing cognitive performance is referred to as domains of cognitive functioning, and there are also subdomains within each domain. These subdomains can be characterised with neuropsychological tests which measure certain abilities (55).

For example, the Mini-Mental State Examination (MMSE) evaluates cognitive function through 30 questions. The cognitive abilities which are assessed include memory, calculation, attention and orientation, language, registration, recall and the ability to draw a polygon. The MMSE can be used to predict the cognitive decline due to dementia in patients with cognitive impairments (56).

The Wechsler Adult Intelligence Scale (WAIS) is a common cognitive battery used to assess IQ in individuals, a proxy of general cognitive functioning. WAIS encompasses four components; the Verbal Comprehension Index, the Perceptual Reasoning Index, the Working Memory Index and the Processing Speed Index (57).

As for testing language abilities, the Boston Naming Test (BNT) is often used as it sensitively detects aphasia and compromised lexical abilities through visual confrontation naming, and the BNT can also be a beneficial test for the differential diagnosis of dementia (58).

The Wisconsin Card Sorting Test (WSCT) evaluates executive functioning – cognitive flexibility, rule learning, problem-solving and certain brain disorders. Participants are required to match test cards to reference cards according to three possible rules: shape, colour or number. Individuals sort the cards through trial and error, but feedback is provided after each match. The rule is made invalid by negative feedback after some successive correct sorting of the cards. The participants are informed of what was previously correct or incorrect, and then they need to search for a new rule (59).

Moreover, there exists the Hopkins Verbal Learning Test (HVLT), which is a short verbal memory test taking approximately 10 minutes to administer. The revised version (HVLT-R) contains a delayed recall trial. HVLT is often used to screen for dementia, as the earliest signs of dementia involve memory issues, including difficulties recalling words (60).

1.5. Cognitive domains

Language processes encompass speech and written language production, auditory function and comprehension. The Superior Temporal Gyrus (at the Temporal lobe) contains the auditory cortex, where auditory input is received (61). In nearly all right-handed individuals and in 60% of left-handed individuals, language function is localised to the left cerebral hemisphere (62). Broca's area is found in the inferior frontal lobe (63), and controls comprehension, speech production and language processing (61). Wernicke's area is located in the posterior part of the Superior Temporal Gyrus (62), and involves processing language comprehension, as well as written and spoken language (61). A lesion in either of these areas leads to a form of aphasia, which is a disruption of cognitive processes involving language (64). Broca's aphasia (also known as motor or expressive aphasia) is an inability to produce language efficiently, as there is disruption of the organisational aspect of the language, such as grammar. With Wernicke's aphasia (also known as sensory or receptive aphasia), there is difficulty understanding spoken language as there is damage in the posterior temporal lobe (65).

Learning involves changes in mental representations which can be manifested as behavioural changes. This is due to interacting with the environment and allowing an individual to adapt to the demands of the environment. The knowledge representations of learning are processed and stored as memory (66). The hippocampus, amygdala and the parahippocampal gyrus are the important structures for memory (67), but the hippocampus has a major role in learning and memory. The hippocampus is an S-shaped structure densely packed with neurons located in the temporal lobe. It is part of the "limbic system", which also encompasses the amygdala. Damage to the hippocampus leads to anterograde and retrograde amnesia (68). Degeneration of the hippocampus, as seen in Alzheimer's disease and alcoholism, can induce short-term memory loss (69).

Additionally, the hippocampus contains three major subdivisions: the dentate gyrus and the CA3/4 and CA1/2 pyramidal cell regions. There is a unidirectional connectivity between these three cell fields, with the granule cells of the dentate gyrus projecting towards the CA3/4 pyramidal cells, which then project to CA1/2 pyramidal cells. The entorhinal cortex provides the major afferents to the dentate via excitatory perforant path fibres, which then activates the excitation of the dentate gyrus, CA3/4 and CA1/2 pyramidal neurons, and this serial propagation is the trisynaptic pathway that is regarded as the principal characteristic of hippocampal physiology (70). The major output from the hippocampus is provided by the CA1 pyramidal cells, which send projections to the amygdala, prefrontal cortex, perirhinal cortex and the neighbouring subiculum. CA1, while being the major output of the hippocampus, is essential for most hippocampal-dependent memory, as lesions in this area lead to severe memory impairment. There is evidence that hippocampal CA1 lesions generate anterograde and retrograde loss of episodic memory (71).

Furthermore, another important feature involving the hippocampus is the Papez circuit, which is a neural loop extending from the hippocampal formation to the mamillary body of the hypothalamus, to the anterior nucleus of the thalamus to the cingulate gyrus of the parahippocampal gyrus, and then back to the hippocampal formation. The significance of this loop is known for its consolidation of declarative memory and for central emotion (72).

Information that one has to recall consciously is known as explicit memory, whereas implicit memory, which includes abilities or skills, can be recalled unconsciously (73). The majority of declarative memory is acquired explicitly, and the majority of nondeclarative memory is acquired implicitly (74). There exist two different types of declarative memory: semantic memory and episodic memory (73). Semantic memory stores factual information, such as knowing the name of the capital city of a country. Episodic memory, however, represents memories with a spatiotemporal context, such as an experience on holiday, a graduation ceremony or one's wedding day. As for nondeclarative memory, most of this knowledge is acquired through procedures (procedural or motor memories) where motor skills are ameliorated, such as riding a bike. The medial temporal lobe structures, such as the hippocampus, is the main area for the function of declarative memory. Nondeclarative memory primarily depends on the cerebellum, striatum and cortical association areas. The two components of declarative memory are the foundation of long-term memory, which is the mechanism where acquired memories are stored permanently and are less afflicted by interference. However, nondeclarative memory, such as procedural memory of a skill, may also be consolidated into long-term memory (74). As for short-term memory, this is the ability to retain a small amount of knowledge for a short period of time. Short-term memory is involved in a system whereby knowledge is retained temporarily for a set of different cognitive processes, such as understanding, learning and reasoning (73).

It is very common for students to feel overwhelmed from the pressure of deadlines and exam performance (75), and this is especially true for medical students (76). Furthermore, stress, a negative emotional state, can either hinder and/or facilitate both learning and memory depending on the duration and intensity. For example, acute and mild stress may enable cognitive performance and learning, whereas chronic and severe stress may be detrimental to learning and memory (77). There is evidence that chronic elevations of cortisol levels lead to a decline in hippocampal activity and hippocampal volume with increasingly dysfunctional hippocampal neurons, and aging also accelerates this loss (78). Certain factors can affect the impact of emotion on learning and memory, such as particular individual differences and age of the students. Personality traits, such as extraversion or neuroticism, could influence a student's response to emotional stimuli and their ability to withstand stress. Gender may also play a role, as sex hormones can contribute to these differences (77). Female students usually have higher anxiety levels and often assess their stressful situations more negatively, which can lead to them suffering more severely and more frequently from stress (76). Age is another important factor contributing to an individual's stress resistance, given that older students have more experience with stress, and therefore have better emotional control and perhaps better learning and memory performance than younger students (77).

The correspondence between the study material and the stressor may also have an influence on the ability to learn. If the stressful event can be relatable to the learning material, it is easier for the student to recall due to its relevance. However, if the stressor is irrelevant to the material, it is difficult for the student to remember this knowledge later on (75).

As for visual processes, the occipital lobe is the primary visual area, and includes functions such as reading and comprehension of reading (61). The retina relays visual information to the primary cortical region of the brain where it is received, integrated and processed (79). The projections pass through the thalamus and neurons, and encode certain properties such as motion, colour and orientation. These projections pass through to the temporal lobes and parietal lobe, and these lobes function together with the visual cortex (61).

Projections passing from the occipital lobe to the temporal lobe facilitates the recognition of faces and objects, whereas visual processes from the occipital lobe to the parietal lobe enable the localisation of objects in space (80).

The primary motor cortex controls the initiation of motor movements and coordination. The primary motor cortex is a component of the motor cortex, which also includes the premotor cortex and supplementary motor area (61). The motor cortex plans and creates electrical impulses which provoke voluntary muscle contractions (81). The premotor cortex contributes to limb movement, as well as to imitation as the form of learning. The supplementary motor area is involved with movements that have already been mentally rehearsed (61).

Attention is a necessary cognitive function for language, memory and perception (82). Attention is a process that is applied to competing environmental information and focusing on one action, while simultaneously filtering out the alternative options. A model describing three attention processes supported by different brain networks was first proposed by Posner and colleagues, and it encompasses alerting, spatial orienting and executive attention. After visual information passes through the lateral geniculate nucleus, it then converges at the cortical nodes. Alerting is where a state of arousal is provoked by an unexpected external stimulus. As for orienting, this action involves shifting attention selectively in one's environment, and it may involve head or eye movement (overt) or it may not be associated to head or eye movement (covert) (83). Executive attention is defined as a process involved in error detection and resolving conflict (82). Attentional control occurs across parietal, temporal and frontal brain areas.

Visual working memory is one's ability to retain visual information for a few seconds, such as colours, letters or shapes. It is also involved in decision-making and action-planning, and therefore highly correlated to intelligence. However, with attentional distraction, there can be an inability to retain information as memory, even for a short period of time. Attention deficits arise when there is damage to the attention network. The parietal cortex area is involved in the voluntary allocation of attention, and if this area is damaged due to, for example, a stroke on the right side of the parietal area, this could lead to a loss of visual awareness on the left side of space. This is known as "neglect", and would result in the patient only eating food on the right side of the plate or not being able to read letters on the left side of a page (84).

It is also considered that speed of perception is a subdomain of cognitive function. In a given direction, motion is detected and integrated by the visual system to produce consistent perception of the moving object (85). Reaction time involves the time taken for sensory perception to initiation of a motor activity as a voluntary response to a stimulus. There is evidence that medical students with more active lifestyles demonstrated a better reaction time, whereas high stress levels have been shown to have a detrimental effect on reaction time. It is therefore prudent that medical students avoid a sedentary lifestyle by exercising regularly, maintain a healthy body weight and avoid substance abuse (86).

Convergent thinking encompasses the use of logic, accuracy and speed, and essentially means the ability to give a correct answer to a question. It is most useful for situations where an already existing answer is ready to be used, and simply needs to be applied appropriately according to the circumstance. There is a strong association between convergent thinking and knowledge, and it is known that convergent thinking does not require much creativity. Divergent thinking, however, uses available information to create multiple or alternative answers. This form of thinking is more creative, and involves seeing new possibilities, taking risks and the ideas produced are unconventional (87).

As for psychomotor skills, another cognitive function, they involve the development of an organised pattern of muscular activities prompted by environmental signals. Coordinated activity with the arms, hands, fingers and feet are particularly emphasised, as they are essential for driving a car and for hand-eye coordination tasks, such as typing, sewing and playing a musical instrument (88). Psychomotor skills can be classified as “fine” and “gross”. Fine motor skills involve the use of smaller muscle groups, such as the hands and fingers, whereas gross motor skills use larger muscle groups, such as the arms or legs. The majority of movements require a combination of fine and gross motor skills. For example, although writing is seen as a fine motor skill, it does require the use of larger muscle groups in the arm.

A feedback loop is necessary for the refinement of psychomotor skills. Perceptive or proprioceptive input creates this feedback loop. Perception is defined as awareness accessed through the five senses (sight, hearing, smell, taste and touch), whereas proprioception is defined as one’s awareness of their body in space. Together, these aspects permit unconscious coordination. Furthermore, coordination and adaptation are two aspects demonstrating profession of psychomotor ability. Coordination pertains to combining psychomotor skills, such as buttoning a shirt, styling hair, typing, building, performing surgery or dancing. Adaptation is the ability to transfer these skills to different contexts. The environment that the task must be performed in, the medium involved (such as typing on a computer or playing the piano) and the criteria of certain aspects of the task (whether one lifts a box once or several times) are all variables concerning the context. The ability to transfer certain psychomotor skills to fulfil new job functions is critical, especially in this day with the evolution of technology (89).

2. OBJECTIVES

The aim of this study is to investigate if there is an association between IQ test scores performed through the Raven's Advanced Progressive Matrices (APM) and cognitive testing through the Complex Reactionmeter Drenovac (CRD) test battery.

The hypotheses of this study are:

1. A higher IQ score achieved on Raven's APM will correlate with a faster and more accurate performance on test of convergent thinking (CRD11) of the CRD test battery.
2. A higher IQ score achieved on Raven's APM will correlate with a faster and more accurate performance on light signal position discrimination test (CRD311) of the CRD test battery.
3. A higher IQ score achieved on Raven's APM will correlate with a faster and more accurate performance on test of operative thinking (CRD411) of the CRD test battery.
4. Men will have a slightly faster performance on the CRD-series tests than women.
5. There will be no differences in IQ assessed with Raven's APM among men and women.

3. SUBJECTS AND METHODS

Ethical approval for this research was obtained from the Biomedical Research Ethics Committee of the USSM (33-1/06).

3.1. Participants

The participants involved in this study were second-year medical students at the University of Split School of Medicine (USSM) studying in the English and Croatian programme. From 2017-2019, a total of 224 subjects were recruited and they were all required to include their age and gender. Exclusion criteria were refusing to participate in this study and not being present. The participants were not asked to prepare in advance for any of the tests. All of the tests were performed in the morning hours between 8 am to 11 am in a quiet laboratory room at the faculty of the USSM.

3.2. Intelligence testing

The IQ scores of the students were measured under test conditions through a printed version of the Raven's Advanced Progressive Matrices (APM). Students had 30 minutes to complete as many of the 36 items of the abstract reasoning test as possible. Each item required the student to identify the missing element that would complete the 3 x 3 matrix of patterns presented. There was increasing difficulty with each test item, and the student was given a choice out of eight possible answers and also a "Do not know" option. The number of items answered correctly out of 36 was the score used for measuring performance on this test.

3.3. Cognitive and psychomotor performance testing

The computerised test of CRD-series was used for testing the cognitive and psychomotor performance of the participants. The time that is needed to process information in this chronometric test represents the psychomotor function of the reaction time (18). Specific knowledge and language skills are not necessary for CRD testing, and it can be performed on any age group (17). For this investigation, three different representative tests from the CRD-series were used in the same order, from the simplest to the most difficult test; the speed of perception test measuring light signal discrimination (CRD311), the test of operative thinking measuring coordinated movements of the participants' upper and lower limbs (CRD411) and the test of convergent thinking through solving simple arithmetic operations of addition and subtraction (CRD11).

Figure 1. CRD device with four panels and a computer.

The CRD311 test measures speed of perception to a visual stimulus. It included 60 tasks, where the subject would see one random sequence of light appearing from a panel of nine square buttons in one row, and was instructed to press the according square below that light as quickly as possible when the light appeared using the index finger of the dominant hand. Once the correct button was pressed, a new light sequence appeared on the panel and the participant had to continue to press the appropriate button under the light until all 60 lights were displayed.

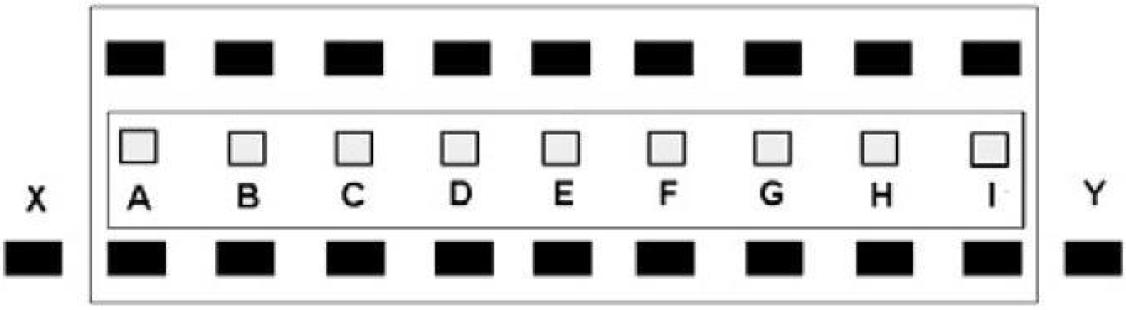

Figure 2. CRD311 test panel showing nine square buttons that the participant must press immediately when they see the light appear above the button.

As for the CRD411 test, which measures complex psychomotor coordination, there was a panel where four lights could appear in four circles arranged with two in the top row and two in the bottom row. Participants would need to press the button with their corresponding hand depending on whether the light appeared on the left or right side in the top row. The two lights of the bottom row, whether left or right, required that the individual pushed the pedal on the floor with their corresponding foot. It was possible for one, two or three lights to appear in this 35-item test, which could involve the student pressing both hands or both feet, or one hand or one foot, or all possible combinations of hands and feet if all three lights appeared. The next task would begin once the previous task was answered correctly, and if more than one light was displayed, the corresponding buttons or pedals had to be pressed simultaneously in order for the participant to answer the task correctly.

In the CRD11 test, there was a panel with 12 lights centrally, organized in four columns and 3 rows. Above each column as well as right or left to each row was a number that had to be used for summation or subtraction. Once the light appeared, it would indicate the numbers just above it and right/left to it to be used in mathematical operation. An additional light with a (+) or with a (-) would appear in the left/right corner of the panel to indicate whether the task needed summation or subtraction. The greatest number on the panel was 13 and there were 35 tasks to solve in order for the test to end. Subjects were instructed to press the correct answer by pressing the result of the sum or the subtraction of the indicated numbers (from 6 to 17), presented in the bottom row. The next task appeared once the student correctly answered the previous task.

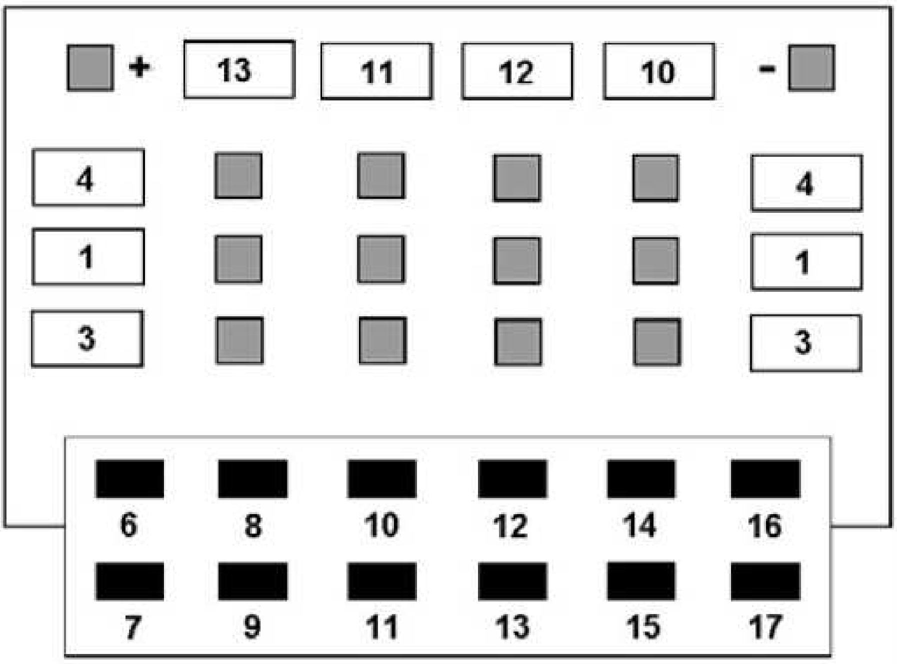

Figure 3. CRD11 test displaying a panel where a light may appear to indicate the numbers above and right/left of it as well as a light appearing at the (+) or (−) at the top of the panel. The respondent then presses the result of the summation or subtraction operation calculated.

Before commencing each CRD test, the student was allowed a trial test to familiarize themselves with the dynamics of the test to prevent overwhelming the participant. Each student had the same variation of each test, so that there were no differences in complexity, and they were all required to complete each test as quickly and accurately.

3.4. Data collection and statistical analysis

For statistical analysis, six parameters of each test of the CRD-series were recorded and analyzed: total test solving time (TTST), minimum single task solving time (MinT), median single task solving time (MedT), start ballast (ST), end ballast (EB), and total ballast (TB). The indicators of speed, accuracy and mental endurance were TTST, MinT and MedT. The ballasts were descriptors of stability and show the time that was wasted and not spent on solving the tests. It was calculated as the sum of differences between time spent on each individual task (Ti) and a minimum single task solving time. Start ballast (SB) represented the wasted time during the first half of the test, the end ballast (EB) during the second half of the test, while the total ballast (TB) was the sum of SB and EB, i.e., total wasted time during the whole test (18).

The IQ scores were collected and compared with the performance scores of each of the CRD-series tests. The age and gender of the students were also collected. All of this data was processed in a table using the spreadsheet software Excel version 11.0 (Microsoft Corporation, Washington, USA).

For statistical analysis MedCalc for Windows, version 11.5.1.0 (MedCalc Software, Mariakerke, Belgium) was used. Categorical data were presented as absolute and relative frequencies, while continuous variables were presented as mean ± standard deviation, and age of subjects was shown as median (minimum, maximum). A comparison of cognitive and psychomotor abilities measured by CRD-series tests between men and women was made using Student's t-test for independent samples. The association between performance on CRD-series tests and Raven's APM intelligence test was tested using Pearson's correlation coefficient. The contribution of CRD-series tests results to Raven's APM test was analysed using multiple linear regression. The level of statistical significance was set at $P < 0.05$.

4. RESULTS

There was a total of 224 medical students involved in this study, of which there were 72 men and 152 women. The minimum age of the students was 19 years, the maximum age was 31 years and the median age was calculated as 21 years (Table 1).

Table 1. Gender and age

	Total N = 224	**Men** N = 72 (32.14%)	**Women** N = 152 (67.86%)
Age (years)	21 (19-31)	21 (19-31)	21 (19-30)
Croatian programme, N (%)	171 (76.3)	49 (68.1)	122 (80.3)
English programme, N (%)	53 (23.7)	23 (31.9)	30 (19.7)

Age is shown as median (minimum-maximum)

On the test of convergent thinking (CRD11), it was found that men had significantly shorter task solving times for both TTST (97.52 ± 18.82 *vs.* 107.69 ± 20.57, P < 0.001) and MinT (1.64 ± 0.28 *vs.* 1.79 ± 0.30, P < 0.001) than women. Male students also had significantly reduced ballast times (*P* = 0.0370, *P* = 0.0237 and *P* = 0.0151; for EB, SB and TB, respectively) compared with those of women (Table 2).

As for the light signal position discrimination test (CRD311), it was demonstrated that men had a shorter TTST (27.13 ± 2.17s *vs.* 28.13 ± 2.46s, *P* = 0.002), as well as MinT (0.32 ± 0.04 s *vs.* 0.34 ± 0.05, *P* = 0.015) than women. However, there were no significant differences in the ballast times between men and women (Table 2).

On test of operative thinking (CRD411), men had faster reaction times in this limb coordination test than their female counterparts. Men had a TTST of 26.93 ± 5.13 seconds, whereas women had a longer TTST of 30.77 ± 7.26 seconds (*P* < 0.001). Men also had a MinT significantly shorter than that of the women as shown in Table 2 (*P* < 0.001). It was also seen that the start ballast was longer in women (5.16 ± 0.21s *vs.* 4.51 ± 0.17s, *P* = 0.017) than in men, and that the end ballast was also longer in women (9.07 ± 3.25s *vs.* 10.62 ± 4.23s, *P* = <0.001) than in men (Table 2).

Table 2. Performance on CRD-series testing in medical students

	Total N = 224	**Men** N = 72	**Women** N = 152	***P****
CRD11				
TTST (s)	104.38 ± 20.54	97.52 ± 18.82	107.69 ± 20.57	< 0.001
MinT (s)	1.74 ± 0.30	1.64 ± 0.28	1.79 ± 0.30	< 0.001
SB (s)	19.93 ± 7.57	18.53 ± 6.75	20.69 ± 7.84	0.024
EB (s)	23.56 ± 9.28	21.81 ± 7.98	24.41 ± 9.77	0.037
TB (s)	43.49 ± 14.78	40.16 ± 13.38	45.09 ± 15.16	0.015
NoErr	2.92 ± 2.65	2.44 ±2.48	3.15 ± 2.71	0.058
CRD311				
TTST (s)	27.81± 2.41	27.13 ± 2.17	28.13 ± 2.46	0.002
MinT (s)	0.34 ± 0.05	0.32 ± 0.04	0.34 ± 0.05	0.015
SB (s)	4.02 ± 1.01	3.92 ± 0.88	4.07 ± 1.07	0.284
EB (s)	3.71 ± 0.98	3.78 ± 0.99	3.68 ± 0.98	0.479
TB (s)	7.73 ± 1.84	7.70 ± 1.69	7.75 ± 1.92	0.857
CRD411				
TTST (s)	29.52 ± 6.87	26.93 ± 5.13	30.77 ± 7.26	< 0.001
MinT (s)	0.41 ± 0.08	0.38 ± 0.07	0.43 ± 0.07	< 0.001
SB (s)	4.94 ± 0.20	4.51 ± 0.17	5.16 ± 0.21	0.017
EB (s)	10.12 ± 4.02	9.07 ± 3.25	10.62 ± 4.23	< 0.001
TB (s)	15.06 ± 5.54	13.58 ± 4.52	15.77 ± 5.86	0.003
NoErr	8.38 ± 5.54	6.49 ± 4.20	9.30 ± 5.89	< 0.001

Data are presented as mean ± standard deviation

**P* values were calculated with the use of Student t-test

CRD Complex Reactionmeter Drenovac, *TTST* total test solving time, *MinT* minimum single task solving time, *SB* start ballast, *EB* end ballast, *TB* total ballast, *NoErr* number of errors

Although there was so significant difference between men and women regarding the IQ scores achieved on Raven's APM test, men achieved a slightly higher score than women (27.12 ± 4.85 and 26.91 ± 5.01, respectively, $P = 0.344$; Table 3).

Students with an APM score of 34 are ranked within the 95th percentile, meaning that these students achieved a higher APM score than 95% of the other students in the norm group for undergraduate students. An APM score of 21 is within the 5th percentile, and a score of 27 equates to the 50th percentile (Table 4). The medical students in this study have a mean APM score of 27.12 (Table 3), which indicates that on average, these students have an APM score of the 50th percentile ranking for the undergrad students (Table 4). Around 30% of the students achieved an APM score in range of 25 to 28, 33% with a score between 29 to 32 and only 13% excelling with a score of 33 to 36 (Figure 4).

Table 3. APM scores of the students

	Total	**Men**	**Women**	***P****
APM scores	27.12 ± 4.85	27.56 ± 4.52	26.91 ± 5.01	0.344

Data are presented as mean ± standard deviation

**P* value was calculated with the use of Student t-test

Table 4. APM norms for undergrad students

Percentile	**APM result**
95	34
90	32
75	30
50	27
25	24
10	22
5	21

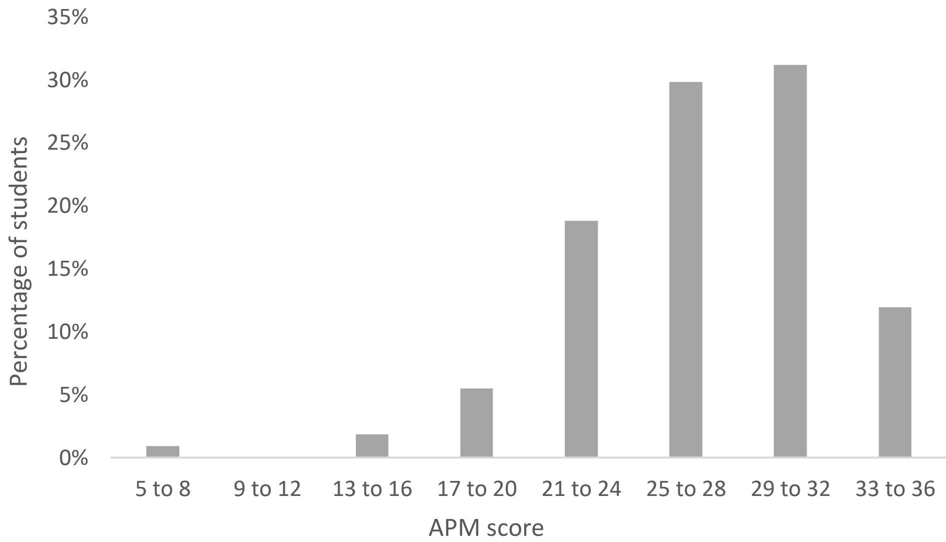

Figure 4. Distribution of APM results in our study group

Using Pearson's correlation coefficient (Table 5), the association between performance on Raven's APM intelligence test and the CRD-series tests was analyzed. This showed that APM scores had a negative correlation with the majority of the CRD-series tests.

On test of convergent thinking (CRD11), task solving times were shorter in students with a higher APM score (r = -0.48 for TTST and r = -0.44 for MinT; $P < 0.001$ for both tests). A similar negative correlation was found for the ballast times and APM scores (r = -0.41, -0.24, -0.36; for SB, EB and TB respectively, all with $P < 0.001$).

On the light signal position discrimination test (CRD311), there are shorter task solving times in correlation with a greater APM score (r = -0.30 for TTST and r = -0.33 for MinT, $P < 0.001$ for both variables). However, there was no significant association between the ballast times and the APM scores of the medical students.

As for the test of operative thinking (CRD411), there was a negative correlation between task solving times and APM scores and with a higher APM score, task solving times were shorter (r = -0.40 for TTST and r = -0.30 for MinT, $P < 0.001$ for both). Ballast times also demonstrated a negative correlation with APM scores (r = -0.41, -0.34 and -0.40 for SB, EB and TB respectively, all with $P < 0.001$).

Table 5. Correlation between APM scores and performance on CRD-series testing

	Total		**Men**		**Women**	
	N = 224		**N = 72**		**N = 152**	
	r	*P**	r	*P**	r	*P**
CRD11						
TTST	-0.48	< 0.001	-0.41	< 0.001	-0.51	< 0.001
MinT	-0.44	< 0.001	-0.38	0.001	-0.45	< 0.001
SB	-0.41	< 0.001	-0.20	0.094	-0.47	< 0.001
EB	-0.24	< 0.001	-0.33	0.005	-0.20	0.013
TB	-0.36	< 0.001	-0.30	0.011	-0.37	< 0.001
NoErr	-0.08	0.233	0.13	0.274	-0.14	0.085
CRD311						
TTST	-0.30	< 0.001	-0.25	0.031	-0.30	< 0.001
MinT	-0.33	< 0.001	-0.25	0.032	-0.35	< 0.001
SB	0.12	0.073	-0.02	0.900	0.18	0.028
EB	0.13	0.052	0.12	0.317	0.13	0.108
TB	0.14	0.036	0.06	0.610	0.17	0.040
CRD411						
TTST	-0.44	< 0.001	-0.37	0.001	-0.46	< 0.001
MinT	-0.30	< 0.001	-0.22	0.068	-0.33	< 0.001
SB	-0.41	< 0.001	-0.23	0.056	-0.48	< 0.001
EB	-0.34	< 0.001	-0.29	0.013	-0.35	< 0.001
TB	-0.40	< 0.001	-0.30	0.011	-0.43	< 0.001
NoErr	-0.15	0.025	-0.08	0.526	-0.15	0.060

**P* values were calculated with the use of Pearson's correlation coefficient

CRD Complex Reactionmeter Drenovac, *TTST* total test solving time, *MinT* minimum single task solving time, *SB* start ballast, *EB* end ballast, *TB* total ballast, *NoErr* number of errors

A multiple linear regression was performed to analyze the contribution of age, gender and CRD-series tests results to APM score (Table 6). Out of the analysed variables, TTST on tests CRD11 and CRD411 (β = -0.182, *P* = 0.009, and β = -0.215, *P* = 0.002, respectively) as well as MinT on test CRD311 (β = -0.158, *P* = 0.023) significantly contributed to APM score.

Table 6. Regression analysis of APM score based on the multiple linear regression model including total test solving time (TTST) and minimum single task solving time (MinT) on CRD11, CRD311 and CRD411 tests, age and gender of medical students assessed in the study

	R^2	*P**	β	t	*P**
Age			-0.132	-1.901	0.059
Gender			0.089	1.278	0.203
CRD11					
TTST			-0.182	-2.650	0.009
MinT			-0.037	-0.531	0.596
CRD311	0.279	< 0.001			
TTST			0.052	0.746	0.457
MinT			-0.158	-2.297	0.023
CRD411					
TTST			-0.215	-3.147	0.002
MinT			< 0.001	0.007	0.994

**P* values were calculated with the use of multiple linear regression

CRD Complex Reactionmeter Drenovac, *TTST* total test solving time, *MinT* minimum single task solving time

5. DISCUSSION

This study is the first to the best of our knowledge to examine the association between IQ test scores performed through the Raven's APM and cognitive abilities testing through Complex Reactionmeter Drenovac (CRD) test battery in medical students. We demonstrated that APM scores had a negative correlation with the majority of the CRD-series tests, implying that students overall with a greater APM score also had better performance on the CRD-series tests.

On the light signal position discrimination tests (CRD311), students with higher APM scores were faster at accurately discriminating light signals than those students with a lower APM score. On the tests of convergent thinking (CRD11) and operative thinking (CRD411), students with higher APM scores were faster at accurately solving simple arithmetic operations, while also having a better stability of performance. Our results are in accordance with the results of the previous studies which confirmed that there is an association between different domains of cognitive performance and IQ tests, and so individuals who excel on one test would also excel on other cognitive tests (16, 90, 91, 92).

We examined the contribution of age, gender and performance on the CRD-series tests results to the APM score, and it was found that task solving times TTST on both tests CRD11 and CRD411 and MinT on test CRD311 had a significant contribution to the APM score. This establishes that shorter task solving times on these two CRD-series tests correlate with a greater APM score.

For the speed of perception test (CRD311), given that it is a subdomain of cognitive function (85), it is no surprise that a higher IQ would lead to a faster response at detecting the light stimulus. Similar results were found in a study exploring the relationship between intelligence and visual recognition memory in adolescents. Intelligence (IQ) was measured using the Raven's Standard Progressive Matrices (RPM) and visual recognition was measured by the subtest Pattern Recognition Memory (PRM) of the Cambridge Neuropsychological Test Automated Battery (CANTAB). The PRM tests visual pattern recognition memory in a 2-choice forced discrimination paradigm. Each participant sees a series of 12 visual patterns one-by-one on the screen and it is required that each subject chooses between a pattern that has already been viewed and a new one, and then the patterns appear in a reversed order. The number and percentage of correct and incorrect answers and the mean correct and incorrect answers latency are measured. A correlation was found between the PRM mean correct and incorrect answers latency and the IQ score from the RPM, where higher scores on RPM were associated with a faster time on answering the PRM test (93).

Furthermore, a Generation R study assessed the relationship of IQ and neurocognition in children. Intelligence was measured through the shortened version of the Snijders-Oomen Niet-verbale intelligentie Test-Revisie, which is a nonverbal IQ test ideal for children aged 2.5 to 7 years. Cognitive performance domains including language, memory and learning, attention and executive functioning, visual processing and sensorimotor functioning, were assessed using the Developmental Neuropsychological Assessment-second edition-Dutch edition (NEPSY-II-NL). It was revealed that children with a greater IQ score performed significantly better on the NEPSY-II-NL test and the strongest relationship was seen on the tasks involving the visuospatial processing domain (94), further supporting our observation that an increased IQ score is correlated with an improved performance on the test of speed of perception. Thus, one might presume that the students with higher IQ scores are probably more likely to process information at a faster rate.

Our results revealed that a better performance on the test of convergent thinking (CRD11) correlates with a higher IQ. This is probably due to being able to provide correct answers quickly to these arithmetic operations, and medical students in general often already have had greater mathematical knowledge and arithmetic skills with secondary school grades for maths reflecting this. The Mini-Mental Sate Examination (MMSE) assesses convergent thinking through calculation (56). A positive correlation between scores on the Peabody Picture Vocabulary Test-Revised (PPVT-R) and cognitive performance on the MMSE was revealed in a study involving elderly patients (90). PPVT-R estimates IQ by measuring one-word receptive vocabulary, and this test was moderately correlated with scores from the Raven Matrices (95). This relationship was found in both; patients with no brain dysfunction and patients with either Parkinson's, Alzheimer's or cerebrovascular disease. This study therefore revealed that a greater IQ score would lead to an improved cognitive performance on the MMSE (90), including convergent thinking, which is also represented in our study.

Likewise, a greater IQ score associated with faster reaction times on the test of operative thinking (CRD411) could be explained by a greater speed of processing (16) and possibly better attention. A previous study examined the correlations between results on IQ test and the MATRICS Consensus Cognitive Battery (MCCB), which measured seven domains of cognitive function: attention, speed of processing, verbal learning, visual learning, working memory, social cognition and problem-solving. This study proved that those with greater IQ scores performed better on the MCCB, especially regarding the speed of processing domain (16).

MyCognition Quotient (MyCQ) is an online test battery that through 10 subtests measures five primary cognitive domains: attention, psychomotor speed, episodic memory, working memory and executive functioning. A previous showed that the majority of the MyCQ domains correlated with each other. In particular, it was also seen that a higher IQ score was associated with better performances on the MyCQ psychomotor test and executive functioning test (92). This further reinforces the evidence of greater IQ score correlating with a better achievement on the test of operative thinking (CRD411) used in our study. Another study demonstrated the same correlation between IQ testing and cognitive performance, including simple psychomotor abilities such as finger tapping speed. WAIS and WAIS-R Full-Scale IQ scores and their association with performance on the cognitive test battery consisting of the Wide Range Achievement Test (WRAT), the Halstead-Reitan Battery (HRB) and the Wechsler Memory Scale (WMS) were investigated. A strong relationship was found between IQ score and scores on memory tasks, auditory and linguistic measures, problem-solving tasks, tactual imperceptions and academic achievement levels in heterogeneous adult neuropsychiatric samples. There was especially a strong association between IQ and WRAT score, as well as with education level and academic achievement in these subjects (91).

Our results revealed that gender had an effect on the performance on the CRD-series tests, but not on the Raven’s APM tests. More precisely, shorter reaction times and shorter ballasts on the tests of convergent thinking (CRD11) and those of operative thinking (CRD411) indicated that the male students were in general faster and had more stable performance than women at solving these simple arithmetic operations and in psychomotor coordination, respectively. It was also seen that men had shorter reaction times on the light signal position discrimination test (CRD311) than women. Our results further support previous findings which have identified that males usually have better calculation skills (26) and they typically have better motor and visuospatial skills, while females are better in verbal abilities (25). While there is evidence that females and males share several similarities regarding their cognitive abilities, there exists a large difference for motor performance whereby males usually have better results than females in this cognitive ability (33). This is also demonstrated by a previous investigation also studying the association of gender and performance on the CRD-series tests, which revealed that men achieved better results than women on convergent thinking (CRD11) and psychomotor (CRD411) tests. The type and style of playing as a child most likely permitted better performance in the psychomotor testing in men (96).

This study is not without limitations. Even though the majority of the participants were students of the Croatian programme, we believe that this did not influence the results, given that neither APM nor CRD-series tests are culture or language sensitive. Furthermore, it is convincing that the student's academic abilities and education background may have provided them with better cognitive abilities. However, in our study the medical students on average had an APM score of the 50th percentile according to the norms of the undergrad students. Thus, we believe that our study sample was representative for the student population. Other factors such as lifestyle and sleep habits, as well as chronotype might have had impact on the students' performance, especially having in mind that all of the tests were carried out in the morning hours from 8am to 11am. However, we believe that accounting for these confounders would not materially change the observed effects since the observed effects were large.

6. CONCLUSION

6. CONCLUSION

The aims of this research were to investigate the correlations between the IQ score of medical students using the Raven's APM and their cognitive performance through the CRD-series tests, as well as to compare the differences in performance between the men and women of this study. Our results indicate that achieving a higher APM score is associated with a greater performance on the CRD-series tests, and therefore greater cognitive abilities for convergent thinking, operative thinking and speed of perception. Men overall also were slightly better than women on these tests.

7. REFERENCES

1. Kiesewetter J, Ebersbach R, Görlitz A, Holzer M, Fischer MR, Schmidmaier R. Cognitive problem solving patterns of medical students correlate with success in diagnostic case solutions. PLoS One. 2013;8:e71486.
2. Oommen A. Factors Influencing Intelligence Quotient. J Neurol Stroke. 2014;1:00023.
3. Tucker-Drob EM, Briley DA, Harden KP. Genetic and Environmental Influences on Cognition Across Development and Context. Curr Dir Psychol Sci. 2013;22:349-55.
4. Briley DA, Tucker-Drob EM. Explaining the increasing heritability of cognitive ability across development: a meta-analysis of longitudinal twin and adoption studies. Psychol Sci. 2013;24:1704-13.
5. Colom R, Karama S, Jung RE, Haier RJ. Human intelligence and brain networks. Dialogues Clin Neurosci. 2010;12:489–501.
6. Sternberg RJ. Intelligence. Dialogues Clin Neurosci. 2012;14:19-27.
7. Johnson W, Bouchard Jr. TJ, Krueger RF, McGue M, Gottesman I. Just one g: consistent results from three test batteries. Intelligence. 2004;32:95-107.
8. Burkart JM, Schubiger MN, van Schaik CP. The evolution of general intelligence. Behav Brain Sci. 2017;40:e195.
9. Kura K, te Nijenhuis J, Dutton E. Spearman's Hypothesis Tested Comparing 47 Regions of Japan Using a Sample of 18 Million Children. Psych. 2019;1:26-34.
10. Gottfredson LS. g: Highly general and highly practical. The general factor of intelligence: how general is it? Mahwah, NJ: Lawrence Erlbaum Associates Publishers; 2002. p. 331–380.
11. Lilienthal L, Tamez E, Myerson J, Hale S. Predicting performance on the Raven's Matrices: The roles of associative learning and retrieval efficiency. J Cogn Psychol (Hove). 2013;25:10.1080/20445911.2013.791299.
12. Brown R. Hebb and Cattell: The Genesis of the Theory of Fluid and Crystallized Intelligence. Front. Hum. Neurosci. 2016;10:606.
13. Duckworth AL, Quinn PD, Lynam DR, Loeber R, Stouthamer-Loeber M. Role of test motivation in intelligence testing. Proc Natl Acad Sci U S A. 2011;108:7716-20.
14. Ganuthula VRR, Sinha S. The Looking Glass for Intelligence Quotient Tests: The Interplay of Motivation, Cognitive Functioning, and Affect. Front Psychol. 2019;10:2857.
15. Bilker WB, Hansen JA, Brensinger CM, Richard J, Gur RE, Gur RC. Development of abbreviated nine-item forms of the Raven's standard progressive matrices test. Assessment. 2012;19:354–69.

16. Mohn C, Sundet K, Rund BR. The relationship between IQ and performance on the MATRICS consensus cognitive battery. Schizophr Res Cogn. 2014;1:96-100.
17. Pecotic R, Dodig IP, Valic M, Galic T, Lusic Kalcina L, Ivkovic N *et al*. Effects of CPAP therapy on cognitive and psychomotor performances in patients with severe obstructive sleep apnea: a prospective 1-year study. Sleep Breath. 2019;23:41–8.
18. Lusic Kalcina L, Pavlinac Dodig I, Pecotic R, Valic M, Dogas Z. Psychomotor Performance in Patients with Obstructive Sleep Apnea Syndrome. Nat Sci Sleep. 2020;12:183-95.
19. Finn GM, Mwandigha L, Paton LW, Tiffin PA. The ability of 'non-cognitive' traits to predict undergraduate performance in medical schools: a national linkage study. BMC Med Educ. 2018;18:93.
20. Meyer H, Zimmermann S, Hissbach J, Klusmann D, Hampe W. Selection and academic success of medical students in Hamburg, Germany. BMC Med Educ. 2019;19:23.
21. Saguil A, Dong T, Gingerich RJ, Swygert K, LaRochelle JS, Artino Jr AR. Does the MCAT Predict Medical School and PGY-1 Performance?. Military Medicine. 2015;4:4-11.
22. Kadmon G, Kirchner A, Duelli R, Resch F, Kadmon M. Warum der Test für Medizinische Studiengänge (TMS)? [What is the purpose of the German Aptitude Test for Medical Studies (TMS)?]. Z Evid Fortbild Qual Gesundhwes. 2012;106:125-30.
23. Mercer A, Crotty B, Alldridge L, Le L, Vele V. GAMSAT: A 10-year retrospective overview, with detailed analysis of candidates' performance in 2014. BMC Med Educ. 2015;15:31.
24. Brown CA, Lilford RJ. Selecting medical students. BMJ. 2008;336:786.
25. Buczyłowska D, Ronniger P, Melzer J, Petermann F. Sex Similarities and Differences in Intelligence in Children Aged Two to Eight: Analysis of SON-R 2-8 Scores. J Intell. 2019;7:11.
26. Ardila A, Rosselli M, Matute E, Inozemtseva O. Gender differences in cognitive development. Developmental Psychology. 2011;47:984–90.
27. Ingalhalikar M, Smith A, Parker D, Satterthwaite TD, Elliott MA, Ruparel K et al. Sex differences in the structural connectome of the human brain. PNAS. 2014;111:823-8.
28. Hughes P. Can we improve on how we select medical students? J R Soc Med. 2002;95:18-22.
29. Gómez-Pinilla F. Brain foods: the effects of nutrients on brain function. Nat Rev Neurosci. 2008;9:568-78.

30. O' Donovan F, Carney S, Kennedy J. Associations and effects of omega-3 polyunsaturated fatty acids on cognitive function and mood in healthy adults: a protocol for a systematic review of observational and interventional studies. BMJ Open. 2019;9:e027167.
31. Howieson DB [Internet]. New York: Cognitive Skills and the Aging Brain: What to Expect. Dana Foundation. [updated 2015 Dec 1, cited 2020 Jan 2020]. Available from: https://www.dana.org/article/cognitive-skills-and-the-aging-brain-what-to-expect/
32. Murman DL. The Impact of Age on Cognition. Semin Hear. 2015;36:111-21.
33. Jäncke L. Sex/gender differences in cognition, neurophysiology, and neuroanatomy. F1000Res. 2018.;7:F1000 Faculty Rev-805.
34. Zaidi Z. Gender Differences in Human Brain: A Review. The Open Anatomy Journal. 2010;2:37-55.
35. Hegelund ER, Grønkjær M, Osler M, Dammeyer J, Flensborg-Madsen T, Mortensen E. The influence of educational attainment on intelligence. Intelligence. 2020;78:101419.
36. Ritchie SJ, Tucker-Drob EM. How Much Does Education Improve Intelligence? A Meta-Analysis. Psychol Sci. 2018;29:1358-69.
37. Ritchie SJ, Bates TC, Deary IJ. Is education associated with improvements in general cognitive ability, or in specific skills? Dev Psychol. 2015;51:573-82.
38. Hackman DA, Farah MJ, Meaney MJ. Socioeconomic status and the brain: mechanistic insights from human and animal research. Nat Rev Neurosci. 2010;11:651-9.
39. de Neubourg E, Borghans L, Coppens K, Jansen M. Explaining Children's Life Outcomes: Parental Socioeconomic Status, Intelligence and Neurocognitive Factors in a Dynamic Life Cycle Model. Child Indic Res. 2018;11:1495-513.
40. Ashoorion V, Liaghatdar MJ, Adibi P. What variables can influence clinical reasoning?. J Res Med Sci. 2012;17:1170-5.
41. Radfar S, Aghaie M, Motashaker-Arani M, Noohi S, Saburi A. Evaluation of Emotional Intelligence and Its Relation to the Academic Achievement in Medical Students. Thrita. 2013;2:113-9.
42. O'Connor PJ, Hill A, Kaya M, Martin B. The Measurement of Emotional Intelligence: A Critical Review of the Literature and Recommendations for Researchers and Practitioners. Front Psychol. 2019;10:1116.
43. Wijekoon CN, Amaratunge H, de Silva Y, Senanayake S, Jayawardane P, Senarath U. Emotional intelligence and academic performance of medical undergraduates: a cross-sectional study in a selected university in Sri Lanka. BMC Med Educ. 2017. doi: 10.1186/s12909-017-1018-9.

44. Kiesewetter J, Ebersbach R, Tsalas N, Holzer M, Schmidmaier R, Fischer MR. Knowledge is not enough to solve the problems - The role of diagnostic knowledge in clinical reasoning activities. BMC Med Educ. 2016;16:303.
45. Wood DF. Problem based learning. BMJ. 2003;326:328-30.
46. Qin Y, Wang Y, Floden RE. The Effect of Problem-Based Learning on Improvement of the Medical Educational Environment: A Systematic Review and Meta-Analysis. Med Princ Pract. 2016;25:525-32.
47. Thampy H, Willert E, Ramani S. Assessing Clinical Reasoning: Targeting the Higher Levels of the Pyramid. J Gen Intern Med. 2019;34:1631-6.
48. Robbins TW. Cognition: the ultimate brain function. Neuropsychopharmacology. 2011;36:1–2.
49. Ackerman S. Discovering the Brain. Washington (DC) [Internet]: National Academies Press (US); Learning, Recalling, and Thinking. [updated 1992, cited 2020 Sep 18]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK234153/
50. Juárez Olguín H, Calderón Guzmán D, Hernández García E, Barragán Mejía G. The Role of Dopamine and Its Dysfunction as a Consequence of Oxidative Stress. Oxid Med Cell Longev. 2016;2016:9730467.
51. Švob Štrac D, Pivac N, Mück-Šeler D. The serotonergic system and cognitive function. Transl Neurosci. 2016;7:35-49.
52. Borodovitsyna O, Flamini M, Chandler D. Noradrenergic Modulation of Cognition in Health and Disease. Neural Plast. 2017;2017:6031478.
53. Ferreira-Vieira TH, Guimaraes IM, Silva FR, Ribeiro FM. Alzheimer's disease: Targeting the Cholinergic System. Curr Neuropharmacol. 2016;14:101-15.
54. Porges EC, Woods AJ, Edden RA, Puts NA, Harris AD, Chen H et al. Frontal Gamma-Aminobutyric Acid Concentrations Are Associated With Cognitive Performance in Older Adults. Biol Psychiatry Cogn Neurosci Neuroimaging. 2017;2:38-44.
55. Harvey PD. Domains of cognition and their assessment. Dialogues Clin Neurosci. 2019;21:227–37.
56. Arevalo-Rodriguez I, Smailagic N, Roqué I Figuls M, Ciaponni A, Sanchez-Perez E, Giannakou A et al. Mini-Mental State Examination (MMSE) for the detection of Alzheimer's disease and other dementias in people with mild cognitive impairment (MCI). Cochrane Database Syst Rev. 2015;2015:CD010783.

57. Bulzacka E, Meyers JE, Boyer L, Le Gloahec T, Fond G, Szöke A et al. WAIS-IV Seven-Subtest Short Form: Validity and Clinical Use in Schizophrenia, Archives of Clinical Neuropsychology. 2016;8:915–25.
58. Jefferson AL, Wong S, Gracer TS, Ozonoff A, Green RC, Stern RA. Geriatric performance on an abbreviated version of the Boston naming test. Appl Neuropsychol. 2007;14:215-23.
59. Wang J, Cao B, Cai X, Gao H, Li F. Brain Activation of Negative Feedback in Rule Acquisition Revealed in a Segmented Wisconsin Card Sorting Test. PLoS One. 2015;10:e0140731.
60. Grenfell-Essam R, Hogervorst E, W Rahardjo TB. The Hopkins Verbal Learning Test: an in-depth analysis of recall patterns. Memory. 2018;26:385-405.
61. Gain U. The cognitive function and the framework of the functional hierarchy. Applied Computing and Informatics. 2018;16:81-116.
62. Acharya AB, Wroten M. Wernicke Aphasia. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; [updated 2020 Aug 10, cited 2020 Sep 17]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK441951/
63. Acharya AB, Wroten M. Broca Aphasia. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; [Updated 2019 Dec 15, cited 2020 Sep 17]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK436010/
64. Tippett DC, Niparko JK, Hillis AE. Aphasia: Current Concepts in Theory and Practice. J Neurol Transl Neurosci. 2014;2:1042.
65. Purves D, Augustine GJ, Fitzpatrick D, et al., editors. Neuroscience. 2nd edition. Sunderland (MA): Sinauer Associates; 2001. Aphasias. Available from: https://www.ncbi.nlm.nih.gov/books/NBK10972/
66. Stern E. Individual differences in the learning potential of human beings. NPJ Sci Learn. 2017;2:2.
67. Squire LR, Wixted JT. The cognitive neuroscience of human memory since H.M. Annu Rev Neurosci. 2011;34:259-88.
68. Anand KS, Dhikav V. Hippocampus in health and disease: An overview. Ann Indian Acad Neurol. 2012;15:239-46.
69. Ackerman S. Discovering the Brain. Washington (DC): National Academies Press (US); 1992. 2, Major Structures and Functions of the Brain.

70. Yeckel MF, Berger TW. Feedforward excitation of the hippocampus by afferents from the entorhinal cortex: redefinition of the role of the trisynaptic pathway. Proc Natl Acad Sci U S A. 1990;87:5832-6.
71. Basu J, Siegelbaum SA. The Corticohippocampal Circuit, Synaptic Plasticity, and Memory. Cold Spring Harb Perspect Biol. 2015;7:a021733.
72. Choi S, Kim Y, Paek S, Cho Z. Papez Circuit Observed by in vivo Human Brain With 7.0T MRI Super-Resolution Track Density Imaging and Track Tracing. Front Neuroanat. 2019;13:17.
73. Camina E, Güell F. The Neuroanatomical, Neurophysiological and Psychological Basis of Memory: Current Models and Their Origins. Front Pharmacol. 2017;8:438.
74. Brem AK, Ran K, Pascual-Leone A. Learning and memory. Handb Clin Neurol. 2013;116:693-737.
75. Vogel S, Schwabe L. Learning and memory under stress: implications for the classroom. NPJ Sci Learn. 2016;1:16011.
76. Nechita F, Nechita D, Pîrlog MC, Rogoveanu I. Stress in medical students. Rom J Morphol Embryol. 2014;55:1263-6.
77. Tyng CM, Amin HU, Saad MNM, Malik AS. The Influences of Emotion on Learning and Memory. Front Psychol. 2017;8:1454.
78. McAuley MT, Kenny RA, Kirkwood TB, Wilkinson DJ, Jones JJL, Miller VM. A mathematical model of aging-related and cortisol induced hippocampal dysfunction. BMC Neurosci. 2009;10:26.
79. Huff T, Mahabadi N, Tadi P. Neuroanatomy, Visual Cortex. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing. [updated 2020 Jul 31, cited 2020 Sep 17]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK482504/
80. Moodley A. Understanding vision and the brain. Community Eye Health. 2016;29:61-3.
81. Yip DW, Lui F. Physiology, Motor Cortical. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing. [updated 2020 Aug 16, cited 2020 Sep 18]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK542188/
82. Posner MI, Rothbart MK, Voelker P. Developing brain networks of attention. Curr Opin Pediatr. 2016;28:720-4.
83. Amso D, Scerif G. The attentive brain: insights from developmental cognitive neuroscience. Nat Rev Neurosci. 2015;16:606-19.
84. Lodge JM, Harrison WJ. The Role of Attention in Learning in the Digital Age. Yale J Biol Med. 2019;92:21-8.

85. Jogan M, Stocker A. Signal Integration in Human Visual Speed Perception. Journal of Neuroscience. 2015;35:9381-90.
86. Kasozi KI, Mbiydzneyuy NE, Namubiru S, et al. A study on visual, audio and tactile reaction time among medical students at Kampala International University in Uganda. Afr Health Sci. 2018;18:828-36.
87. Cropley A https://www.tandfonline.com/doi/abs/10.1207/s15326934crj1803_13
88. Noble CE, Cratty BJ. Psychomotor Learning [Internet]. Encyclopaedia Britannica. [updated 2016 Apr 1, cited 2020 Sep 18]. Available from: https://www.britannica.com/science/psychomotor-learning
89. Hill KL, Fadel C, Bialik M. Psychomotor Skills for the 21st Century: What should students learn? [Internet]. Center for Curriculum Redesign. [updated 2018 Apr, cited 2020 Sep 18]. Available from: http://curriculumredesign.org/wp-content/uploads/Psychomotor-Skills-CCR-May2018.pdf
90. Bieliauskas LA, Depp C, Kauszler ML, Steinberg BA, Lacy M. IQ and scores on the Mini-Mental State Examination (MMSE). Aging, Neuropsychology, and Cognition. 2000;4: 227–9.
91. Warner MH, Ernst J, Townes BD, Peel J, Preston M. Relationships Between IQ and Neuropsychological Measures in Neuropsychiatric Populations: Within-Laboratory and Cross-Cultural Replications Using WAIS and WAIS-R. J Clin Exp Neuropsychol. 1987;5:545-62.
92. Domen AC, van de Weijer SCF, Jaspers MW, Denys D, Nieman DH. The validation of a new online cognitive assessment tool: The MyCognition Quotient. Int J Methods Psychiatr Res. 2019;28:e1775.
93. Zakharov IM, Voronin IA, Ismatullina VI, Malykh SB. The Relationship between Visual Recognition Memory and Intelligence. Procedia - Social and Behavioral Sciences. 2016;233:313-7.
94. Mous SE, Schoemaker NK, Blanken LME, Thijssen S, van der Ende J, Polderman TJC et al. The association of gender, age, and intelligence with neuropsychological functioning in young typically developing children: The Generation R study, Applied Neuropsychology: Child. 2017;1:22-40.
95. Krasileva KE, Sanders SJ, Bal VH. Peabody Picture Vocabulary Test: Proxy for Verbal IQ in Genetic Studies of Autism Spectrum Disorder. J Autism Dev Disord. 2017;4:1073-85.

96. Pavlinac Dodig I, Krišto D, Lušić Kalcina L, Pecotić R, Valić M, Đogaš Z. The effect of age and gender on cognitive and psychomotor abilities measured by computerized series tests: a cross-sectional study. Croat Med J. 2020;2:82-92.

8. SUMMARY

Objectives: The aim of this study is to investigate the correlations between IQ test scores performed through the Raven's Advanced Progressive Matrices (APM) and cognitive testing through the Complex Reactionmeter Drenovac (CRD) test battery.

Subjects and methods: From 2017-2019, 224 medical students at the University of Split School of Medicine (USSM) studying in the English and Croatian programme were recruited for this study. The IQ scores of the students were assessed using Raven's APM where students had 30 minutes to complete 36 items of the abstract reasoning test. The computerised test of CRD-series was used for testing reaction times of light stimulus perception (CRD311), complex psychomotor limb coordination (CRD411) and solving simple arithmetic operations (CRD11). The total test solving time (TTST) and the minimum single task solving time (MinT), were analyzed.

Results: On test of convergent thinking (CRD11), task solving times were shorter in students with a higher APM score ($r = -0.48$ for TTST and $r = -0.44$ for MinT; $P < 0.001$ for both tests. The light signal position discrimination test (CRD311) had shorter task solving times in correlation with a greater APM score ($r = -0.30$ for TTST and $r = -0.33$ for MinT, $P < 0.001$ for both variables). The test of operative thinking (CRD411) also demonstrated a negative correlation between task solving times and APM scores and with a higher APM score, task solving times were shorter ($r = -0.40$ for TTST and $r = -0.30$ for MinT, $P < 0.001$ for both). Men displayed a significantly shorter TTST than women on these tests; CRD11 (97.52 ± 18.82s *vs.* 107.69 ± 20.57s, $P < 0.001$), CRD311(27.13 ± 2.17s *vs.* 28.13 ± 2.46s, $P = 0.002$) and on CRD411 (26.93 ± 5.13s *vs.* 30.77 ± 7.26s, $P < 0.001$).

Conclusion: This study concludes that achieving a higher APM score is associated with a greater performance on the CRD-series tests, and therefore greater cognitive abilities for convergent thinking, operative thinking and speed of perception. Men overall also were slightly better than women on these tests.

9. CROATIAN SUMMARY

Naslov: Povezanost rezultata u različitim domenama kognitivnih sposobnosti studenata medicine

Ciljevi: Cilj ove studije je istražiti povezanost između inteligencije ispitane pomoću Ravenovih naprednih progresivnih matrica (APM) i kognitivnih sposobnosti ispitanih testovima Complex Reactionmeter Drenovac (CRD) serije.

Materijali i metode: Od 2017. do 2019. godine u ovom istraživanju sudjelovalo je 224 studenta medicine Medicinskog fakulteta Sveučilišta u Splitu koji studiraju na engleskom ili hrvatskom programu. Inteligencija studenata izmjerena je pomoću Ravenovih APM-a gdje su studenti tijekom 30 minuta rješavali 36 zadataka testa apstraktnog rasuđivanja. Kompjuterizirani test CRD serije korišten je za ispitivanje vremena reakcije prilikom percepcije svjetlosnih podražaja (CRD311), složene psihomotoričke koordinacije udova (CRD411) i rješavanja jednostavnih aritmetičkih operacija (CRD11). Od rezultata postignutim na testovima analizirani su ukupno vrijeme rješavanja testa (TTST) i najkraće vrijeme rješavanja jednog zadatka (MinT).

Rezultati: Na testu konvergentnog mišljenja (CRD11) vrijeme rješavanja zadataka bilo je kraće u studenata s višim APM rezultatom ($r = -0{,}48$ za TTST i $r = -0{,}44$ za MinT; $P < 0{,}001$ za oba testa). Na testu razlikovanja položaja svjetlosnog signala (CRD311) vremena rješavanja zadataka su bila kraća u studenata s višim APM rezultatom ($r = -0{,}30$ za TTST i $r = -0{,}33$ za MinT, $P < 0{,}001$ za obje varijable). Na testu operativnog mišljenja (CRD411) također je pronađena negativna korelacija između vremena rješavanja zadataka i rezultata APM-a ($r = -0{,}40$ za TTST i $r = -0{,}30$ za MinT, $P < 0{,}001$ za oba). Muškarci su imali kraće TTST od žena na testovima: CRD11 ($97{,}52 \pm 18{,}82$s vs. $107{,}69 \pm 20{,}57$s, $P < 0{,}001$), CRD311 ($27{,}13 \pm 2{,}17$s vs. $28{,}13 \pm 2{,}46$s, $P = 0{,}002$) i na CRD411 ($26{,}93 \pm 5{,}13$s vs. $30{,}77 \pm 7{,}26$ s, $P < 0{,}001$).

Zaključci: Ovo istraživanje pokazalo je da je bolji APM rezultat povezan s boljim učinkom na testovima CRD serije, a time i boljim kognitivnim sposobnostima za konvergentno mišljenje, operativno mišljenje i brzinu percepcije. Muškarci su također bili nešto bolji od žena na ovim testovima.

10. CURRICULUM VITAE

Personal Data:

Name: Aisha Samia Qazzafi
Date of birth: 11th June 1996
Citizenship: British
Place of birth: West Bromwich
Email: aishaqazzafi@ymail.com

Education:

MD 2015-2021: University Split School of Medicine, Croatia
Diploma in Information Technology 2014-2015: The Manchester College, England
3 A-levels 2012-2014: Parrs Wood Sixth Form College, England
10 GCSEs 2010-2012: Manchester High School for Girls, England

Clinical attachments:

Feb 2021: Cardiology department, Warrington and Halton Hospital, Warrington, UK
Sep 2019: General Medicine & Diabetology, Warrington and Halton Hospital, Warrington, UK
Jul 2019: Pediatrics, Warrington and Halton Hospital, Warrington, UK
Sep 2018: Cardiology, Warrington and Halton Hospital, Warrington, UK
Sep 2018: Cardiology, Manchester Royal Infirmary, Manchester, UK

Activities:

Member of “Medic Sibling” programme
Active member of ISA Split (International Student Association)