https://doi.org/10.1590/1980-5764-DN-2022-0004

Neuropsychological findings in migraine: a systematic review

Hanna Hakamäki[1], Mervi Jehkonen[1,2]

ABSTRACT. Patients with migraine often experience cognitive dysfunction during a migraine attack, but they have also been reported to complain about cognitive impairment after an attack and during the interictal period. **Objective:** The aim of this study was to determine what neuropsychological test methods are used to assess cognitive functioning in migraine patients and to examine the neuropsychological findings in adult (≥18 years) migraineurs compared to adult (≥18 years) healthy controls (HC). **Methods:** A systematic review was conducted on the literature published between 2012 and the present. The search results were screened and additional studies identified in the lists of references in the selected articles. A total of 16 articles met the inclusion criteria. **Results:** The 16 articles included in the review compared chronic migraineurs (CM), migraineurs with (MwA) and without aura (MwoA), and migraineurs without aura classification (MIG) to HC. A total of 45 neuropsychological assessment methods were identified. CM and MwA were found to perform significantly worse than HC in executive function, attention, and visual functioning. Additionally, both MwA and MwoA performed significantly worse than HC in memory functions. CM and both MwA and MwoA also performed significantly worse than HC in general cognitive functioning. Surprisingly, MIG performed significantly better than HC in several cognitive domains, including executive, motor, and language functioning and general cognitive functioning. **Conclusions:** This systematic review mostly concurs with the results of an earlier systematic review on the topic from 2012, but with the important addition that different migraine diagnostic groups should be assessed separately.

Keywords: Adult; Cognition; Migraine Disorders; Neuropsychological Tests.

ACHADOS NEUROPSICOLÓGICOS NA ENXAQUECA: UMA REVISÃO SISTEMÁTICA

RESUMO. Pacientes com enxaqueca frequentemente apresentam disfunção cognitiva durante uma crise, mas também foram relatadas queixas de comprometimento cognitivo após uma crise e durante o período interictal. **Objetivo:** Determinar quais métodos de testes neuropsicológicos são usados para avaliar o funcionamento cognitivo em pacientes com enxaqueca e examinar os achados neuropsicológicos em adultos (≥ 18 anos) com enxaqueca em comparação com adultos (≥ 18 anos) controles saudáveis (CS). **Métodos:** Foi realizada uma revisão sistemática da literatura publicada entre 2012 e o presente. Os resultados da pesquisa foram selecionados e estudos adicionais identificados nas listas de referências nos artigos selecionados. Dezesseis artigos preencheram os critérios de inclusão. **Resultados:** Os 16 artigos incluídos na revisão compararam enxaqueca crônica (EC), enxaqueca com (EcA) e sem aura (EsA), e enxaqueca sem classificação de aura (E) em CS. Foram identificados 45 métodos de avaliação neuropsicológica. Indivíduos com EC e EcA apresentaram desempenho significativamente pior do que CS em função executiva, atenção e funcionamento visual. Além disso, tanto a EcA quanto a EsA tiveram desempenho significativamente pior do que em CS nas funções de memória. A EC, a EcA e a EsA também tiveram desempenho significativamente pior do que CS no funcionamento cognitivo geral. Surpreendentemente, a E teve um desempenho significativamente melhor do que os CS em vários domínios cognitivos, incluindo o funcionamento executivo, motor e de linguagem e o funcionamento cognitivo geral. **Conclusões:** Esta revisão sistemática concorda principalmente com os resultados de uma revisão sistemática anterior sobre o tema de 2012, mas com o importante adendo de que diferentes grupos diagnósticos de enxaqueca devem ser avaliados separadamente.

Palavras-chave: Adulto; Cognição; Transtornos de Enxaqueca; Testes Neuropsicológicos.

INTRODUCTION

Migraine is a primary headache disease causing moderate-to-severe pain attacks[1]. It differs from tension-type headache in that migraine pain has a unilateral localisation; the pain is pulsating in quality;

This study was conducted by the Group of Adult Neuropsychology, Tampere University, Tampere, Finland.

[1]Tampere University, Faculty of Social Sciences, Tampere, Finland.

[2]Tampere University Hospital, Tays Research Services, Tampere, Finland.

Correspondence: Hanna Hakamäki; Email: hanna.hakamaki@outlook.com.

Disclosure: The authors report no conflicts of interest.

Funding: This study was financially partly supported by Competitive State Research Financing of the Expert Responsibility Area of Tampere University Hospital.

Received on January 29, 2022; Received in its final form on March 10, 2022; Accepted on March 30, 3022.

and the intensity of pain varies from moderate to severe. Attacks may last from a few hours to up to 3 days and may be associated with nausea and/or vomiting. Another common symptom of migraine is sensitivity to lights or sounds during attacks[1]. Migraine is classified as having aura symptoms (migraine with aura) if the symptoms listed above are accompanied with fully reversible visual, sensory, speech and/or language, motor, brainstem, or retinal aura. Migraine is diagnosed as chronic when the patient has more than 15 headache days per month and 8 or more of these headaches meet the migraine criteria[1].

In a large population study in the United States, 11.7% of participants over the age of 12 years suffered from migraine[2]. The prevalence of migraine has been reported to be highest in middle life (age 35–45 years), and it is roughly twice or even three times more common in women than in men[2,3]. According to the 2016 Global Burden of Disease Study, it is one of the leading causes of disability globally[4]. Several triggering factors are known to provoke an attack: stress and relaxation after stress, normal female hormonal cycle and changes in it, irregular meals, alcohol, certain odours or foods, low levels of magnesium in brain tissue, or altered levels of signal substances, such as serotonin (5-HT)[5].

In addition to pain and other symptoms, migraine patients have consistently reported cognitive dysfunction during migraine attacks. A 2018 systematic review on cognitive functioning during a migraine attack seems to confirm that cognitive dysfunctions do indeed occur in both the headache phase and the postdrome phase of migraine[6]. The most reported cognitive dysfunctions during a migraine attack were related to concentration problems and difficulties in attention. Lower intellectual capacity or "fog" was also reported[6].

Abnormalities in white matter are common in long-standing and highly frequent migraine, and it seems that they are a result rather than the cause of migraine[7,8]. However, Evans et al.[7] reported that clinically meaningful abnormalities requiring intervention in the migraineur's central nervous system were relatively rare. Kruit et al.[8], in contrast, found that especially migraineurs with aura had a higher prevalence of subclinical infarcts in the posterior circulation and that migraineurs in general had a higher prevalence of brainstem hyperintense lesions. However, in the absence of longitudinal assessments, it is still unclear whether these imaged lesions and abnormalities have relevant functional correlates and whether they can explain possible dysfunctions in a migraineur's cognitive functioning.

If migraine can cause abnormalities in brain tissue[5,7,8], then it is reasonable to assume that migraineurs might perform worse than healthy non-migraineurs on neuropsychological assessment, even during the interictal period. Evidence to this effect would contribute to a better understanding of migraine and the burden it places on the people affected. The most recent systematic review on the effect of migraine on cognition interictally was published in 2012[9]. In this review, de Araújo et al.[9] reported that adult migraineurs performed worse than healthy controls (HC) in the following cognitive domains: memory, attention, information processing speed, and executive function. In memory functions, decline was detected in recognition memory[10], verbal and visual memory[11,12], and working memory[13]. In attention, migraineurs showed declined performance compared to HC in sustained attention[10,11], concentration[14], and verbally supported attention[12]. Additionally, Hooker and Raskin[10] and Zeitlin and Oddy[15] reported decline in information processing speed, while Calandre et al.[16] reported that migraineurs performed worse than HC in visual-motor processing. In executive functions, Meyer et al.[14] reported that migraineurs' capacity to solve problems and judgment changes was declined compared to HC. Furthermore, Mongini et al.[13] reported that migraineurs' ability to plan their actions was declined compared to HC. However, de Araújo et al.[9] did not report their results according to different migraine diagnoses, and therefore, the effects of chronicity and aura symptoms remained unclear. The systematic review in 2012 was also unable to ascertain whether these findings were directly associated with migraine. Therefore, it encouraged further studies with greater methodological refinement[9].

The possible impacts of migraine on cognitive functioning warrant closer investigation, as this could give a clearer picture of the underlying causes of possible cognitive decline. This is especially important in later years of life when cognitive decline can be a symptom of dementia. The effects of migraine on cognitive functions outside attacks have been studied from at least the 1980s[15], but controversy continues to surround the issue.

This study reviews the literature published during the past decade (2012–2021) on the effects of migraine on cognition. Neuropsychological methods play a key part in diagnosing and identifying changes in cognitive functioning. However, there are no global standards on what tests should be used to assess migraineurs' cognitive functioning; as a result, multiple different methods are used. This review focuses on neuropsychological findings in adult (≥18 years) migraineurs. We have two research questions:

- What neuropsychological test methods are used to assess cognitive functioning in migraine patients? and

- What the neuropsychological findings in migraineurs are compared to HC?

METHODS

This systematic review was conducted according to the guidelines for Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P 2015 statement)[17]. The search was conducted on 13 February 2021, in the following databases: Cinahl, Pubmed MEDLINE, PsycArticles, Ovid PsycINFO, Scopus, and Web of Science. The search terms used were *migraine* combined with *cognition* or *cognitive* and *neuropsychological assessment* or *evaluation* or *test*. The search was limited to the period from 2012 to the present. No language limitations were applied. Detailed search strategies for all the databases are presented in Supplementary material.

The following inclusion criteria were applied:

- studies on patients with migraine (episodic, chronic, and with or without aura) were included if;
- the studies compared adult (≥18 years) migraine patients' cognitive functioning to adult (≥18 years) HC;
- migraine patients' cognitive functioning was assessed in the interictal period; and
- cognitive functioning was assessed with neuropsychological test methods. Single case studies and non-English articles were excluded.

Cluster headache and other types of headache patients were also excluded. Additionally, the reference lists of the articles retrieved from the database were screened for additional studies. The quality of the studies included was appraised with the AXIS Scale[18]. The quality assessment is provided in Supplementary material (Table S1).

RESULTS

The database search yielded 545 articles, of which 159 duplicates were removed. Additionally, 20 articles were retrieved from the reference lists. Out of the 406 articles screened based on title and abstract, 373 were excluded because they did not meet the inclusion criteria. The remaining 33 full texts were assessed for eligibility. A further 17 articles were judged not to meet the inclusion criteria, leaving 16 articles for this systematic review. The exclusion reasons and number of articles excluded based on these reasons are presented in the PRISMA flowchart (Figure 1).

The following data were retrieved from the articles included in the review: patient's diagnostic statuses and diagnostic criteria, sample size, age at examination, gender, neuropsychological assessment methods, and results on the relation of migraine and neuropsychological functioning. The information extracted from the articles is presented in Table 1.

The articles reviewed are also described in Table 1[19-34]. The articles compared HC to patients with different migraine statuses: migraine without aura (MwoA),

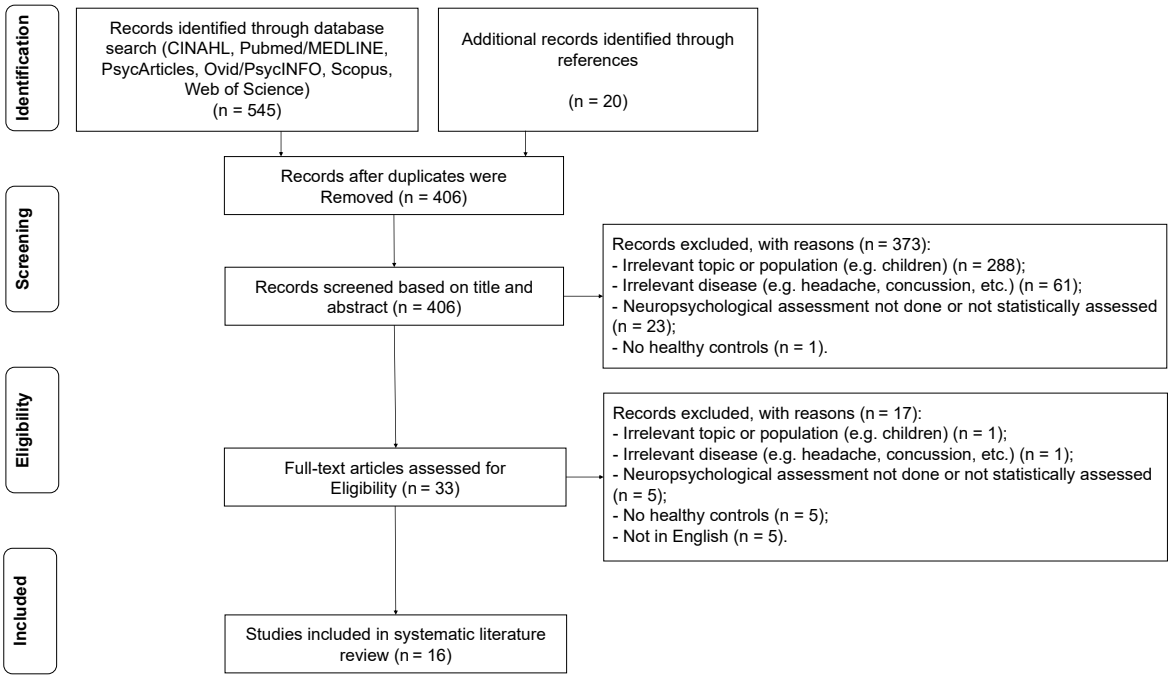

Figure 1. PRISMA flowchart of the systematic literature search.

Table 1. Description of the studies reviewed and the neuropsychological findings comparing migraineurs and healthy controls.

Study	Sample size and migraine diagnosis	Age at examination mean (sd)	Gender (male/ female, n)	Neuropsychological assessment methods	Results on the relation of migraine and neuropsychological functioning
Baschi et al., 2019[19]	Total: n=42 MwoA: n=21 HC: n=21	29.0 (64.3) 27.9 (3.2)	18/24 9/12 9/12	Corsi Test, Buschke Selective Reminding Test, Trail-Making Test (TMT) A and B	MwoA performed significantly better than HC only in tasks evaluating visuospatial memory (short-term p=0.002; long-term p=0.001).
Dresler et al., 2012[24]	Total: n=55 (130)* MIG: n=24 HC: n=31	37.4 (NA) 38.4 (NA)	21/34 5/19 16/15	TMT, Go/No-go Task and Stroop Task	MIG differed significantly from HC only in the Stroop interference task (p=0.04).
Ferreira et al., 2018[27]	Total: n=60 CM: n=30 HC: n=30	33.7 (11.2) 33.7 (9.7)	2/58 1/29 1/29	Montreal Cognitive Assessment (MoCA), Verbal Fluency Test, Stroop Test, Color Trails Test, Wechsler Adult Intelligence Scale (WAIS-III) Digit Span (digits forward), Vocabulary and Matrix Reasoning; Rey Auditory Verbal Learning Test (RAVLT)	CM performed worse than HC in MoCA (p=0.00), Verbal Fluency (p=0.00), Clock Drawing Test (p=0.00), Stroop Test (p=0.01), WAIS-III Digit Span (p=0.00), and WAIS-III Matrix Reasoning (p=0.01). In a linear regression model, CM continued to be an independent factor predicting lower performance compared to HC in Verbal Fluency, Clock Drawing Test, and Stroop Test.
Gil-Gouveia et al., 2016[20]	Total: n=48 MwoA: n=24 HC: n=24	33.3 (7.2)	12/36 6/18 6/18	Finger Tapping, TMT, Stroop Test, Wechsler Memory Scale (WMS-III) – Reverse Digit Span, Phonemic Verbal Fluency, the Aachen Aphasia Test, naming of five compound nouns.	All patients underwent neuropsychological tests twice (average time between tests was 45 days, sd 13.6 days). No significant differences were found between MwoA and HC in performance between first and second evaluation or in test performances between evaluations.
Han et al., 2019[21]	Total: n=64 MwoA: n=32 HC: n=32	38.0 (8.9) 39.1 (11.4)	26/38 12/20 14/18	Mini-Mental State Examination (MMSE), Stroop Test, Shape Trail Test (STT), Attentional Networks Test (ANT)	Significant differences were found only in Stroop III (p=0.03) and STT B (p=0.001). MwoA performed worse than HC. In ANT, MwoA demonstrated significantly longer response times in executive control tasks (p=0.01).
Huang et al., 2017[29]	Total: n=58 MwA; n=10 MwoA: n=24 HC: n=24	36.1 (10.1) 36.1 (13.0)	12/46 6/28 6/18	MoCA, Rey-Osterrieth Complex Figure Test (ROCFT), Digit Symbol Substitution Test (DSST)	Migraineurs performed significantly worse in MoCA total (p=0.007) and in language (p=0.005), executive functions (p=0.042), memory (p=0.006), orientation (p=0.012), and calculation tasks (p=0.018). Migraineurs also performed worse than HC in ROCFT recall (p=0.012).
Le Pira et al., 2014[30]	Total: n=60 MwA: n=12 MwoA: n=32 HC: n=16	42.1 (10.2) 36.7 (9.7) 35.8 (12.6)	11/49 1/11 7/25 3/13	Frontal Assessment Battery (FAB), TMT, Controlled Oral Word Association Test (COWAT), Stroop Test, Boston Scanning Test (BST)	In FAB, MwA performed significantly worse than MwoA (p=0.003) and HC (p=0.0001). In BST, HC performed significantly better than MwA (p=0.0001) and MwoA (p=0.001). In COWAT, a significant difference in performance was reported between HC and MwoA (p=0.001).
Lo Buono et al., 2019[31]	Total: n=150 MwA: n=50 MwoA: n=50 HC: n=50	41.1 (14.1) 38.3 (11.8) 38.2 (11.3)	NA NA NA NA	Attentive Matrices (AT), TMT, RAVLT, Semantic and Phonemic Verbal Fluency	Migraineurs performed worse than HC in RAVLT delayed memory (MwA: p=0.001; MwoA: p=<0.001) and in TMT-B compared to HC (MwA: p=0.005; MwoA: p=<0.001). MwoA performed significantly worse in Semantic Verbal Fluency than HC (p=0.02).
Martins et al., 2012[25]	Total: n=428*(478) MIG: n=61 HC: n=367	61.9 (7.6) 66.8 (9.0)	159/269 5/56 154/213	MMSE, California Verbal Learning Test, WMS-III – visual reproduction and faces I, TMT, Semantic and Phonemic Verbal Fluency, Stroop Test, Digit Span, Symbol Search, Wechsler Abbreviated Scale of Intelligence (WASI) – vocabulary, matrix reasoning, information, Famous Faces Test.	MIG were found to have a significantly lower performance in Symbol Search Test compared to HC (p<0.001). No other statistically significant differences were found between MIG and HC. MIG were significantly younger than non-migraine headache patients and HC and scores from neuropsychological tests were not adjusted by age.

Continue...

Table 1. Continuation.

Study	Sample size and migraine diagnosis	Age at examination mean (sd)	Gender (male/ female, n)	Neuropsychological assessment methods	Results on the relation of migraine and neuropsychological functioning
Baena et al., 2018[32]	Total: n=2466 (4208)* MwA: n=435 MwoA: n=804 HC: n=1227	48.1 (7.2) 49.5 (7.9) 55.3 (9.4)	1075/ 1391 82/353 216/588 777/450	Consortium to Establish a Registry for Alzheimer's Disease Word List Memory Test (CERAD-WLMT), Semantic Fluency Test (SFT), and TMT-B	In CERAD-WLMT, both migraine groups performed significantly worse than HC (p<0.001). After adjusting for gender, age, race, education level, and physical illnesses, no significant differences were found. In SFT, no significant differences were found. In TMT-B, MwA (p=0.005) performed worse than HC. After adjusting, MwoA performed significantly worse than HC (p=0.01; p=0.03).
Padilla et al., 2016[33]	Total: n=63 MwA: n=24 MwoA: n=16 HC: n=23	25.0 (5.8) 27.0 (6.8) 25.0 (4.7) 24.0 (5.0)	17/46 5/19 4/12 8/15	Complutense Verbal Learning Test (TAVEC), ROCFT, Grober and Buschke Free and Cued Selective Reminding Test (FCSRT)	In the ROCFT direct and percentile copy strategy, both migraine groups performed significantly worse than HC (p>0.001). After merging the two migraine groups, the study found significant differences in the ROCFT direct and percentile copy strategy and in direct and percentile recall between migraineurs and HC, with migraineurs performing worse (p=0.001).
Santangelo et al., 2016[22]	Total: n=144 MwoA: n=72 HC: n=72	34.9 (11.2) 33.8 (11.9)	15/129 9/63 6/66	MoCA	Migraineurs performed significantly lower than HC on the total MoCA score (p<0.001) and on attention (p<0.001), memory (p<0.001), visuospatial (p<0.001), and executive domains (p=0.001).
Santangelo et al., 2018[23]	Total: n=175 MwoA: n=91 HC: n=84	33.8 (10.5) 32.3 (10.4)	34/141 16/75 18/66	MoCA, Memory for Intentions Screening Test (MIST)	Migraineurs had significantly lower MoCA scores than HC (p=0.003). In MIST, migraineurs achieved lower scores on time-based (p<0.001) and event-based (p=0.018) tasks than HC.
Wen et al., 2016[26]	Total: n=6420 (6708)* MIG: n=1021 HC: n=5399	63.8 (11.1) 65.9 (11.4)	2675/3645 191/830 2584/2815	MMSE, 15-word Learning Test, Letter–Digit Substitution Test, Stroop Test, Verbal Fluency Test, Purdue Pegboard Test	MwA had the highest mean difference in general cognition compared to HC in MMSE. Migraineurs as a group performed better than HC on the Stroop colour-naming and colour–word interference subtasks. Migraineurs also scored higher on the Verbal Fluency Test and Purdue Pegboard Test. No p-values were presented.
Yetkin-Ozden et al, 2015[34]	Total: n=111 MwA: n=21 MwoA: n=53 HC: n=37	35.3 (12.0) 38.9 (10.5) 36.1 (11.6)	22/89 13/61 9/28	Benton Face Recognition Test (BFRT), Line Orientation Test (LOT)	Migraineurs showed significantly lower performance in both BFRT (p=0.027) and LOT scores (p=0.014) compared to HC. Additionally, MwoA showed significantly lower performance in BFRT than MwA (p=0.031).
Zucca, et al., 2020[28]	Total: n=93 CM: n=37 EM: n=27 HC: n=29	46.1 (11.3) 45.1 (12.2) 42.9 (14.8)	30/63 9/28 9/18 12/17	Wisconsin Card Sorting Test (WCST)	Migraineurs presented worse performance when compared to HC in accuracy score (p=0.012), global monitoring (p=0.015), monetary gains (p=0.022), and control sensitivity (p=0.027). Also, comparing CM to EM patients, CM performed significantly worse in accuracy score (p<0.001), free-choice improvement (p=0.004), global monitoring (p=0.001), monetary gains (p=0.001), and control sensitivity (p<0.001).

CM: chronic migraine; EM: episodic migraine; HC: healthy controls; MIG: migraine (aura not classified); MwA: migraine with aura; MwoA: migraine without aura; NA: not available; *Other participants also included.

migraine with aura (MwA), migraine without the classification of aura symptoms (MIG), chronic migraine (CM), and episodic migraine (EM). MwoA was compared to HC in five studies[19-23], but there were no studies that compared only MwA to HC. Three studies compared MIG to HC[24-26], and two studies compared CM or EM to HC[27,28]. Six studies included patients with both MwA and MwoA and HC[29-34].

The mean quality of the studies included was 16.1 when evaluated with the AXIS Scale[18]. Sample sizes ranged from 42 to 6,420 participants. Most of the studies had 175 participants or fewer. Participants' mean age ranged from 27.0 to 48.1 years in MwA patients, from 25.0 to 49.5 years in MwoA patients, from 37.4 to 63.8 years in MIG patients, and from 33.7 to 46.1 years in CM patients. The mean age of HC ranged from 24.0 to 66.8 years. One study also included EM patients, whose mean age was 45.1 years[28]. All studies except Lo Buono et al.[31] reported the gender distribution of the participants. In all studies, females accounted for more than half of the participants: the proportion of female migraineurs varied from 57.1 to 99.7%. The gender distribution for HC was similar: the proportion of female participants varied from 46.7% to 96.6%.

Migraine and migraine status were mainly diagnosed using the *International Classification of Headache Disorders* (*ICHD*) third edition (beta version, 2013)[19-23,27,29,31,33] or second edition (2004)[24,26,30,32,34-36]. Zucca et al.[28] used the *ICHD-III* (2018)[1] and Martins et al.[25] used the ID-Migraine[37] to diagnose migraine and migraine status.

All neuropsychological test methods used in the articles reviewed are presented according to cognitive domain in Table 2[19-34,38-70]. In the 16 articles, the cognitive performance of migraineurs and HC was assessed

Table 2. Neuropsychological test methods used to assess cognition according to cognitive domain.

Cognitive domain	Neuropsychological test	Articles in which the test method was used
Executive functions and attention	The Attentional Networks Test (ANT)[38]	Han et al., 2019[21]
	The Attentive Matrices (AT)[39]	Lo Buono et al., 2019[31]
	The Boston Scanning test[40]	Le Pira et al., 2014[30]
	The Color Trail Test[41]	Ferreira et al., 2018[27]
	The Digit Symbol Substitution Test (DSST)[29]	Huang et al., 2017[29]
	The Frontal Assessment Battery (FAB)[42]	Le Pira et al., 2014[30]
	The Go/No-go Task[43]	Dresler et al., 2012[24]
	The Letter-Digit Substitution Test[44]	Wen et al., 2016[26]
	The Memory for Intentions Screening Test (MIST)[45]	Santangelo et al., 2018[23]
	The Rey-Osterrieth Complex Figure Test (ROCFT)[46,47]	Huang et al., 2017[29]; Padilla et al., 2016[33]
	The Shape Trail Test (STT)[21]	Han et al., 2019[21]
	The Stroop Test[48]	Dresler et al., 2012[24]; Ferreira et al., 2018[27]; Gil-Gouveia et al., 2016[20]; Han et al., 2019[21]; Le Pira et al., 2014[30]; Martins et al., 2012[25]; Wen et al., 2016[26]
	The Trail-Making Test A and B[49]	Baschi et al., 2019[19]; Dresler et al., 2012[24]; Gil-Gouveia et al., 2016[20]; Le Pira et al., 2014[30]; Lo Buono et al., 2019[31]; Martins et al., 2012[25]; Baena et al., 2018[32]
	The Wechsler Adult Intelligence Scale (WAIS-III) – Digit Span, forward[50]	Ferreira et al., 2018[27]; Martins et al., 2012[25]
	The Wechsler Memory Scale III (WMS-III) – The Reverse Digit Span[51]	Gil-Gouveia et al., 2016[20]
	The Wisconsin Card Sorting Test (WCST)[52]	Zucca et al., 2020[28]
Memory	The Grober and Buschke Free and Cued Selective Reminding Test[53]	Padilla et al., 2016[33]
Visual memory	The Corsi Test[54]	Baschi et al., 2019[19]

Continue...

Table 2. Continuation.

Cognitive domain	Neuropsychological test	Articles in which the test method was used
	The Wechsler Memory Scale III (WMS-III) – Visual Reproduction[50]	Martins et al., 2012[25]
Verbal memory	The 15-Word Learning Test[26]	Wen et al., 2016[26]
	The Buschke Selective Reminding Test[55]	Baschi et al., 2019[19]
	The California Verbal Learning Test (CVLT)[56]	Martins et al., 2012[25]
	The Complutense Verbal Learning Test (TAVEC)[57]	Padilla et al., 2016[33]
	The Consortium to Establish a Registry for Alzheimer's Disease Word List Memory Test (CERAD-WLMT)[58]	Baena et al., 2018[32]
	The Rey Auditory Verbal Learning Test (RAVLT)[59]	Ferreira et al., 2018[27]; Lo Buono et al., 2019[31]
Language function	The Aachen Aphasia Test, naming of five compound nouns[60]	Gil-Gouveia et al., 2016[20]
	The Controlled Oral Word Association Test (COWAT)[61]	Le Pira et al., 2014[30]
	The Phonemic Verbal Fluency[62]	Gil-Gouveia et al., 2016[20]
	The Semantic Fluency Test[63]	Baena et al., 2018[32]
	The Semantic and Phonemic Verbal Fluency[25,31]	Lo Buono et al., 2019[31]; Martins et al., 2012[25]
	The Verbal Fluency Test[26,27]	Ferreira et al., 2018[27]; Wen et al., 2016[26]
Language function	The Wechsler Abbreviated Scale of Intelligence (WASI) – Information[64]	Martins et al., 2012[25]
	The Wechsler Abbreviated Scale of Intelligence (WASI) – Vocabulary[64]	Martins et al., 2012[25]
	The Wechsler Adult Intelligence Scale (WAIS-III) – Vocabulary[50]	Ferreira et al., 2018[27]
Visual function	The Line Orientation Test (LOT)[65]	Yetkin-Ozden et al., 2015[34]
	The Wechsler Abbreviated Scale of Intelligence (WASI) – Matrix Reasoning[64]	Martins et al., 2012[25]
	The Wechsler Adult Intelligence Scale (WAIS-III) – Matrix Reasoning[50]	Ferreira et al., 2018[27]; Martins et al., 2012[25]
	The Wechsler Adult Intelligence Scale III (WAIS-III) – Symbol Search[50]	Martins et al., 2012[25]
Facial recognition	The Benton face recognition test (BFRT)[66]	Yetkin-Ozden et al., 2015[34]
	The Famous Faces Test[25]	Martins et al., 2012[25]
	The Wechsler Memory Scale III (WMS-III) – Faces 1[51]	Martins et al., 2012[25]
Motor function	The Finger Tapping Test[67]	Gil-Gouveia et al., 2016[20]
	The Purdue pegboard Test[68]	Wen et al., 2016[26]
General screening tests	Mini-Mental State Examination (MMSE)[69]	Han et al., 2019[21]; Martins et al., 2012[25]; Wen et al., 2016[26]
	Montreal Cognitive Assessment (MoCA)[70]	Ferreira et al., 2018[27]; Huang et al., 2017[29]; Santangelo et al., 2016[22]; Santangelo et al., 2018[23]

with a total of 45 different neuropsychological test methods, addressing different cognitive domains. These neuropsychological test methods are divided into the following cognitive domains: executive functions and attention, memory, language functions, visual functions, and motor functions. Memory functioning tests were further divided into general memory, visual memory, and verbal memory functioning. Also, a subcategory of facial recognition was added in the visual functions category. Some studies furthermore applied general cognition screening tests. Arithmetic functions were not assessed in any of the studies.

In addition to descriptive facts about the articles included in the review, Table 1 presents the main neuropsychological findings for each article. Overall, the articles reported contradictory findings on all migraine groups compared to HC. The clearest differences were seen in executive functions, attention, and verbal memory, where especially MwA performed worse than HC. For CM, the clearest differences compared to HC were reported in executive functions and attention[27,28]. Even though some differences were also reported in other cognitive domains, no firm conclusions can be drawn about the performance of CM compared to HC in these domains. Across the various fields of cognition, almost all articles reported no significant differences between MIG and HCs. In contrast, MIG actually performed significantly better than HC in executive, motor, and language functioning and, in general, cognitive functioning[25,26].

Comparisons of MwA to HC also yielded contradictory results. The clearest differences were reported in executive functions, attention, and verbal memory. No significant differences were reported between MwA and HC in language functions[30-32]. A significantly worse performance was reported for MwA than HC in both visual functioning and general cognitive functioning[29,34]. Additionally, it was reported that MwA performed significantly worse than MwoA in executive and visual functions[34]. Comparisons of MwoA and HC yielded no clear conclusions on any of the cognitive domains, except general cognitive functioning[21-23].

DISCUSSION

The aim of this systematic review was to determine what neuropsychological test methods are used to assess cognitive functioning in migraine patients and to explore the neuropsychological findings in migraineurs compared to HC. The review included 16 articles which compared adult (≥18 years) CM, EM, MIG, MwA, and/or MwoA to adult (≥18 years) HC using neuropsychological test methods.

The articles used a wide range and a large number of neuropsychological test methods: a total of 45 different tests were applied in the articles included in this systematic review. The fields of cognition that received the most attention were executive functioning and attention, which were studied in 14 articles with 16 different test methods[19-33]. The most commonly used methods were executive functioning and attention tests, the Stroop test, and the Trail-Making test. The least studied field of cognition was motor functioning, which was tested with two different tests[20,26].

The neuropsychological findings were quite diverse. The clearest differences were reported between CM and HC and between MwA and HC in executive functioning. In memory functioning, MwA were reported to perform significantly worse than HC in verbal memory[31,32], but the comparisons between MwoA and HC yielded less conclusive results[19,31,32]. All migraine groups were reported to perform worse than HC in visual functioning, but no firm conclusions can be drawn because of the sporadic results[27,34]. Additionally, migraineurs quite consistently performed worse than HC on general cognitive functioning[22,23,27,29]. For language and motor functioning, however, differences between migraine groups and HC were not reported consistently enough and possible differences were rarely reported. Surprisingly, MIG performed significantly better than HC in several cognitive domains: executive, motor, and language functioning and general cognitive functioning[25,26]. It is also notable that MwA were reported to perform significantly worse than MwoA in executive and visual functions[34].

In the most recent systematic review on the subject from 2012, de Araújo et al.[9] reported that migraineurs performed worse than HC in the following cognitive domains: memory, attention, information processing speed, and executive function. The results of this review seem to be quite closely in line with this, since the clearest differences were seen in executive functions, attention, and memory. However, de Araújo et al.[9] did not report the results according to different migraine diagnoses. It has been shown that the severity of abnormalities imaged in the brain can be affected by the length and frequency of the migraine disease and by the presence of aura symptoms[8]. Therefore, migraineurs who suffer from chronicity and aura symptoms might have more severe neuropsychological dysfunctions, and this is why we have chosen to report the results of neuropsychological assessments according to migraine diagnosis. This proved to be a justified decision as we found that MwA and MwoA differed from each other in two cognitive domains[34]. Furthermore, CM was reported to differ from EM in one cognitive domain[28]. Although differences between migraine groups are not commonly reported, these few differences underscore the importance of studying migraine groups separately.

This systematic review furthers our understanding of the effects of migraine on cognition and shows how the subject has been studied over the past decade. It provides evidence on which cognitive domains are potentially affected by migraine and sheds light on the neuropsychological test methods that could be used — and currently are being used — to assess migraineurs' cognition in the interictal phase. Drawing from several databases, the review comprises a reasonable number of articles that were selected based on titles, abstracts,

and full texts. This provides a strong foundation for drawing meaningful conclusions. Having said that, it is important to note that the large number of test methods used in the articles makes direct comparisons between the studies rather difficult. Even though all studies assessed migraineurs' cognition in a clinical setting, not all of the test methods used can be regarded as equally applicable. For example, the Mini-Mental State Examination (MMSE), which was used by Han and colleagues[21], Martins et al.[25], and Wen et al.[26], has been criticized for its lack of sensitivity to detect minor cognitive changes[71].

The participants in the studies included in the review differed in terms of their demographic characteristics. The age and gender distributions varied across the studies, and a few studies reported that their migraineurs and HC were not demographically matched. Martins et al.[25] reported that their migraineurs were significantly younger, lower educated, and scored higher on a depression scale than HC and that they did not adjust the test scores by age. In a few studies, migraineurs were also reported to score higher on anxiety and depression than HC[21,29,32]. Such differences are only to be expected as migraine has been found to be comorbid with several psychiatric conditions, especially affective and anxiety disorders and even bipolar disorder[72-74]. Some studies reported that psychiatric disorders – for example, anxiety – negatively impacted cognitive functioning[75,76]. It is also noteworthy that some studies had quite small sample sizes or varying sample sizes in different groups of participants, which limits the validity of correlation analysis[24,25,29,33,34]. More carefully selected participant groups and larger sample sizes are needed to obtain more accurate or comparable results.

The aim of this systematic review was to determine what neuropsychological test methods are being used to assess cognitive functioning in migraine patients and to examine the neuropsychological findings in adult migraineurs compared to HC. The finding suggests that CM might be at higher risk of cognitive dysfunction, especially in the domains of executive function, attention, and visual functioning. Similar results were reported for MwA, as MwA were found to perform worse than HC, especially in the domains of executive function, attention, memory, and visual function. It is also suggested that MwoA might be at higher risk of cognitive dysfunction, especially in memory functioning. Based on our systematic review, it is not possible to draw any firm conclusions regarding the cognitive functioning of MIG.

This review concurs with the results of an earlier systematic review on the topic but makes the important addition that different migraine diagnostic groups should be assessed separately. It also concludes that more research is needed on the neuropsychological findings associated with migraine and that, in this work, greater focus should be given to ensuring the demographic consistency of the participant groups, larger sample sizes, and a more careful choice of neuropsychological test methods in order to ensure statistical quality and comparability. Migraine is known to be one of the leading global causes of disability, a major burden on health care systems, and a source of substantial financial and social losses. It has profound adverse effects on the economy more generally and on the everyday lives and quality of lives of people who live with migraine. The possible impact of migraine on cognitive functioning warrants further research, especially in the case of aging migraineurs in later years of life, which is why it is important to continue to pursue a deeper understanding of the disease.

Authors' contributions. HH: main writer, substantial contribution to the design of the study project and the acquisition, analysis, and interpretation of data. Intellectual contribution in writing the manuscript, approved the final version to be published, and agreed to the responsibility of all aspects of the work. MJ: supervisor and mentor of the review, substantial contribution to the design of the study project and the acquisition, analysis, and interpretation of data. Intellectual contribution in critical reviewing of the manuscript, approved the final version to be published, and agreed to the responsibility of all aspects of the work.

REFERENCES

1. Headache Classification Committee of the International Headache Society (IHS). The International Classification of Headache Disorder, 3rd edition. Cephalalgia. 2018;38(1):1-211. https://doi.org/10.1177/0333102417738202
2. Lipton RB, Bigal ME, Diamond M, Freitag F, Reed ML, Stewart WF, et al. Migraine prevalence, disease burden, and the need for preventive therapy. Neurology. 2007;68(5):343-9. https://doi.org/10.1212/01.wnl.0000252808.97649.21
3. World Health Organization. Headache disorders [Internet]. 2016 [cited on Apr 15, 2021]. Available from: https://www.who.int/news-room/fact-sheets/detail/headache-disorders
4. GBD 2016 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet. 2017;390(10100):1211-59. https://doi.org/10.1016/S0140-6736(17)32154-2
5. Linde M. Migraine: a review and future directions for treatment. Acta Neurol Scand. 2006;114(2):71-83. https://doi.org/10.1111/j.1600-0404.2006.00670.x

6. Gil-Gouveia R, Martins IP. Clinical description of attack-related cognitive symptoms in migraine: a systematic review. Cephalalgia 2018;38(7):1335-50. https://doi.org/10.1177/0333102417728250
7. Evans RW, Burch RC, Frishberg BM, Marmura MJ, Mechtler LL, Silberstein SD, et al. Neuroimaging for migraine: the American Headache Society systematic review and evidence-based guideline. Headache. 2020;60(2):318-36. https://doi.org/10.1111/head.13720
8. Kruit MC, van Buchem MA, Launer LJ, Terwindt GM, Ferrari MD. Migraine is associated with an increased risk of deep white matter lesions, subclinical posterior circulation infarcts and brain iron accumulation: the population-based MRI CAMERA study. Cephalalgia. 2010;30(2):129-36. https://doi.org/10.1111/j.1468-2982.2009.01904.x
9. de Araújo CM, Barbosa IG, Lemos SMA, Domingues RB, Teixeira AL. Cognitive impairment in migraine: a systematic review. Dement Neuropsychol. 2012;6(2):74-9. https://doi.org/10.1590/S1980-57642012DN06020002
10. Hooker WD, Raskin NH. Neuropsychologic alterations in classic and common migraine. Arch Neurol. 1986;43(7):709-12. https://doi.org/10.1001/archneur.1986.00520070065020
11. Le Pira F, Zappalà G, Giuffrida S, Lo Bartolo ML, Reggio E, Morana R, et al. Memory disturbances in migraine with and without aura: a strategy problem? Cephalalgia 2000;20(5):475-8. https://doi.org/10.1046/j.1468-2982.2000.00074.x
12. Le Pira F, Lanaia F, Zappalà G, Morana R, Panetta M, Reggio E, et al. Relationship between clinical variables and cognitive performances in migraineurs with and without aura. Funct Neurol. 2004;19(2):101-5. PMID: 15274516
13. Mongini F, Keller R, Deregibus A, Barbalonga E, Mongini T. Frontal lobe dysfunction in patients with chronic migraine: a clinical-neuropsychological study. Psychiatry Res. 2005;133(1):101-6. https://doi.org/10.1016/j.psychres.2003.12.028
14. Meyer JS, Thornby J, Crawford K, Rauch GM. Reversible cognitive decline accompanies migraine and cluster headaches. Headache 2000;40(8):638-46. https://doi.org/10.1046/j.1526-4610.2000.040008638.x
15. Zeitlin C, Oddy M. Cognitive impairment in patients with severe migraine. Br J Clin Psychol. 1984;23(Pt 1):27-35. https://doi.org/10.1111/j.2044-8260.1984.tb00623.x
16. Calandre EP, Bembibre J, Arnedo ML, Becerra D. Cognitive disturbances and regional cerebral blood flow abnormalities in migraine patients: their relationship with the clinical manifestations of the illness. Cephalalgia 2002;22(4):291-302. https://doi.org/10.1046/j.1468-2982.2002.00370.x
17. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev. 2015;4(1):1. https://doi.org/10.1186/2046-4053-4-1
18. Downes MJ, Brennan ML, Williams HC, Dean RS. Development of a critical appraisal tool to assess the quality of cross-sectional studies (AXIS). BMJ Open. 2016;6(12):e011458. https://doi.org/10.1136/bmjopen-2016-011458
19. Baschi R, Monastero R, Cosentino G, Costa V, Giglia G, Fierro B, et al. Visuospatial learning is fostered in migraine: evidence by a neuropsychological study. Neurol Sci. 2019;40(11):2343-8. https://doi.org/10.1007/s10072-019-03973-6
20. Gil-Gouveia R, Oliveira AG, Martins IP. Sequential brief neuropsychological evaluation of migraineurs is identical to controls. Acta Neurol Scand. 2016;134(3):197-204. https://doi.org/10.1111/ane.12530
21. Han M, Hou X, Xu S, Hong Y, Chen J, Ma Y, et al. Selective attention network impairment during the interictal period of migraine without aura. J Clin Neurosci. 2019;60:73-8. https://doi.org/10.1016/j.jocn.2018.10.002
22. Santangelo G, Russo A, Trojano L, Falco F, Marcuccio L, Siciliano M, et al. Cognitive dysfunctions and psychological symptoms in migraine without aura: a cross-sectional study. J Headache Pain. 2016;17(1):76. https://doi.org/10.1186/s10194-016-0667-0
23. Santangelo G, Russo A, Tessitore A, Garramone F, Silvestro M, Della Mura MR, et al. Prospective memory is dysfunctional in migraine without aura. Cephalalgia. 2018;38(12):1825-32. https://doi.org/10.1177/0333102418758280
24. Dresler T, Lürding R, Paelecke-Habermann Y, Gaul C, Henkel K, Lindwurm-Späth A, et al. Cluster headache and neuropsychological functioning. Cephalalgia. 2012;32(11):813-21. https://doi.org/10.1177/0333102412449931
25. Martins IP, Gil-Gouveia R, Silva C, Maruta C, Oliveira AG. Migraine, headaches, and cognition. Headache. 2012;52(10):1471-82. https://doi.org/10.1111/j.1526-4610.2012.02218.x
26. Wen K, Nguyen NT, Hofman A, Ikram MA, Franco OH. Migraine is associated with better cognition in the middle-aged and elderly: the Rotterdam Study. Eur J Neurol. 2016;23(10):1510-6. https://doi.org/10.1111/ene.13066
27. Ferreira KS, Teixeira CT, Cáfaro C, Oliver GZ, Carvalho GLP, Carvalho LASD, et al. Chronic migraine patients show cognitive impairment in an extended neuropsychological assessment. Arq Neuropsiquiatr. 2018;76(9):582-7. https://doi.org/10.1590/0004-282X20180085
28. Zucca M, Rubino E, Vacca A, De Martino P, Roveta F, Govone F, et al. Metacognitive impairment in patients with episodic and chronic migraine. J Clin Neurosci. 2020;72:119-23. https://doi.org/10.1016/j.jocn.2019.12.048
29. Huang L, Dong HJ, Wang X, Wang Y, Xiao Z. Duration and frequency of migraines affect cognitive function: evidence from neuropsychological tests and event-related potentials. J Headache Pain. 2017;18(1):54. https://doi.org/10.1186/s10194-017-0758-6
30. Le Pira F, Reggio E, Quattrocchi G, Sanfilippo C, Maci T, Cavallaro T, et al. Executive dysfunctions in migraine with and without aura: what is the role of white matter lesions? Headache. 2014;54(1):125-30. https://doi.org/10.1111/head.12158
31. Lo Buono V, Bonanno L, Corallo F, Palmeri R, Allone C, Lo Presti R, et al. Cognitive functions and psychological symptoms in migraine: a study on patients with and without aura. Int J Neurosci. 2019;129(6):588-92. https://doi.org/10.1080/00207454.2018.1554658
32. Baena CP, Goulart AC, Santos IS, Suemoto CK, Lotufo PA, Bensenor IJ. Migraine and cognitive function: baseline findings from the Brazilian Longitudinal Study of Adult Health: ELSA-Brasil. Cephalalgia. 2018;38(9):1525-34. https://doi.org/10.1177/0333102417737784
33. Padilla MFQ, Pitta P, Lombana-Angel L, Ingram G, Gómez C, Restrepo JA. Differences in executive functions applied to memory processes in people with migraine: a cross-sectional study. Universitas Psychologica. 2016;15(5):1-11. https://doi.org/10.11144/Javeriana.upsy15-5.defa
34. Yetkin-Ozden S, Ekizoglu E, Baykan B. Face recognition in patients with migraine. Pain Pract. 2015;15(4):319-22. https://doi.org/10.1111/papr.12191
35. Headache Classification Committee of the International Headache Society (IHS). The International Classification of Headache Disorders, 3rd edition (beta version). Cephalalgia. 2013;33(9):629-808. https://doi.org/10.1177/0333102413485658
36. Headache Classification Subcommittee of the International Headache Society. The International Classification of Headache Disorders: 2nd edition. Cephalalgia. 2004;24 Suppl 1:9-160. https://doi.org/10.1111/j.1468-2982.2003.00824.x
37. Lipton RB, Dodick D, Sadovsky R, Kolodner K, Endicott J, Hettiarachchi J, et al. A self-administered screener for migraine in primary care: The ID Migraine (TM) validation study. Neurology. 2003;61(3):375-82. https://doi.org/10.1212/01.WNL.0000078940.53438.83
38. Fan J, McCandliss BD, Sommer T, Raz A, Posner MI. Testing the efficiency and independence of attentional networks. J Cogn Neurosci. 2002;14(3):340-7. https://doi.org/10.1162/089892902317361886
39. Spinnler H, Tognoni G. Standardizzazione e taratura italiana di test neuropsicologici: gruppo italiano per lo studio neuropsicologico dell'invecchiamento. Italian Journal of Neurological Sciences. 1987;8:1-120.
40. Weintraub S, Mesulam MM. Mental status assessment of young and elderly adults in behavioral neurology. In Mesulam MM, eds. Principles of behavioral neurology. Philadelphia: Davis; 1985. p. 71-123.
41. Rabelo IS, Pacanaro SV, Rossetti MO, Leme IFAS. Teste das trilhas coloridas: manual profissional. São Paulo: Casa do Psicólogo; 2010.
42. Dubois B, Slachevsky A, Litvan I, Pillon B. The FAB: a Frontal Assessment Battery at bedside. Neurology. 2000;55(11):1621-6. https://doi.org/10.1212/WNL.55.11.1621
43. Simmonds DJ, Pekar JJ, Mostofsky SH. Meta-analysis of Go/No-go tasks demonstrating that fMRI activation associated with response inhibition is task-dependent. Neuropsychologia. 2008;46(1):224-32. https://doi.org/10.1016/j.neuropsychologia.2007.07.015
44. van der Elst W, van Boxtel MPJ, van Breukelen GJP, Jolles J. The Letter Digit Substitution Test: normative data for 1,858 healthy participants aged 24-81 from the Maastricht Aging Study (MAAS): influence of age, education, and sex. J Clin Exp Neuropsychol. 2006;28(6):998-1009. https://doi.org/10.1080/13803390591004428
45. Woods SP, Moran LM, Dawson MS, Carey CL, Grant I, HIV Neurobehavioral Research Center (HNRC) Group. Psychometric characteristics of the memory for intentions screening test. Clin Neuropsychol. 2008;22(5):864-78. https://doi.org/10.1080/13854040701595999
46. Osterrieth PA. Le test de copie d'une figure complexe. Archives de Psychologie. 1944;30(117):286-356.
47. Rey A. L'examin psychologique dans les cas d'escephalopathie traumatique (Les problems). Archives de Psychologie. 1941;28:215-85.
48. Stroop JR. Studies of interference in serial verbal reactions. Journal of Experimental Psychology. 1935;18(6):643-62. https://doi.org/10.1037/h0054651
49. Reitan RM. Validity of the trail making test as an indicator of organic brain damage. Perceptual and Motor Skills. 1958;8(3):271-76. https://doi.org/10.2466/pms.1958.8.3.271

50. Wechsler D. WAIS-III: administration and scoring manual. Wechsler Adult Intelligence Scale. 3rd edition. San Antonio: Psychological Corporation; 1997.
51. Wechsler D. Wechsler Memory Scale (WMS). 3rd manual. San Antonio: Psychological Corporation; 1997.
52. Grant DA, Berg EA. A behavioral analysis of degree of reinforcement and ease of shifting to new responses in Weigl-type card-sorting problem. J Exp Psychol. 1948;38(4):404-11. https://doi.org/10.1037/h0059831
53. Grober E, Ocepek-Welikson K, Teresi JA. The free and cued selective reminding test: evidence of psychometric adequacy. Psychology Science Quarterly. 2009;51(3):266-82.
54. Corsi PM. Human memory and the medial temporal region of the brain [thesis]. Montreal: McGill University, 1972. Available from: https://escholarship.mcgill.ca/downloads/4m90dw30g.pdf
55. Buschke H. Selective reminding for analysis of memory and learning. Journal of Verbal Learning and Verbal Behavior. 1973;12(5):543-50. https://doi.org/10.1016/S0022-5371(73)80034-9
56. Delis D, Kramer J, Kaplan E, Ober BA. California verbal learning test. 2nd ed. San Antonio: Psychological Corporation; 2000.
57. García-Herranz S, Díaz-Mardomingo MC, Peraita H. Evaluation and follow-up of healthy aging and aging with cognitive impairment (MCI) through TAVEC. Anales de Psicología. 2014;30(1):372-89. https://doi.org/10.6018/analesps.30.1.150711
58. Morris J, Heyman A, Mohs RC, Hughes JP, van Belle G, Fillenbaum G, et al. The Consortium to Establish a Registry for Alzheimer's Disease (CERAD). Part I. Clinical and neuropsychological assessment of Alzheimer's disease. Neurology. 1989;39(9):1159-65. https://doi.org/10.1212/wnl.39.9.1159
59. Schmidt M. rey auditory verbal learning test: a handbook. Los Angeles0: Western Psychological Services; 1996.
60. Huber W, Poeck K, Willmes K. The Aachen aphasia test. Adv Neurol. 1984;42:291-303. PMID: 6209953
61. Benton AL, Hamsher KS, Sivan AB. Multilingual aphasia examination. 3rd ed. Iowa: AJA Associates; 1994.
62. Troyer AK, Moscovitch M, Winocur G. Clustering and switching as two components of verbal fluency: evidence from younger and older healthy adults. Neuropsychology. 1997;11(1):138-46. https://doi.org/10.1037/0894-4105.11.1.138
63. Jones S, Laukka EJ, Bäckman L. Differential verbal fluency deficits in the preclinical stages of Alzheimer's disease and vascular dementia. Cortex+ 2006;42(3):347-55. https://doi.org/10.1016/s0010-9452(08)70361-7
64. Wechsler D. Wechsler Abbreviated Scale of Intelligence (WASI). San Antonio: Psychological Corporation: 1999.
65. Benton AL, Hamsher K, Varney NR, Spreen O. Contributions to neuropsychological assessment. New York: Oxford University Press; 1983.
66. Benton AL, Sivan AB, Hamsher K, Varney NR, Spreen O. Benton facial recognition: stimulus and multiple choice pictures. Lutz: Psychological Assessment Resources; 1983.
67. Reitan RM, Wolfson D. The Halstead-Reitan neuropsychological test battery: theory and clinical interpretation. 2nd ed. Tucson: Neuropsychology Press; 1993.
68. Tiffin J, Asher EJ. The Purdue pegboard; norms and studies of reliability and validity. J Appl Psychol. 1948;32(3):234-47. https://doi.org/10.1037/h0061266
69. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading cognitive state of patients for the clinician. J Psychiatr Res. 1975;12(3):189-98. https://doi.org/10.1016/0022-3956(75)90026-6
70. Nasreddine ZS, Phillips NA, Bédirian V, Charbonneau S, Whitehead V, Collin I, et al. The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. J Am Geriatr Soc. 2005;53(4):695-9. https://doi.org/10.1111/j.1532-5415.2005.53221.x
71. Spencer RJ, Wendell CR, Giggey PP, Katzel LI, Lefkowitz DM, Siegel EL, et al. Psychometric limitations of the mini-mental state examination among nondemented older adults: an evaluation of neurocognitive and magnetic resonance imaging correlates. Exp Aging Res. 2013;39(4):382-97. https://doi.org/10.1080/0361073X.2013.808109
72. Antonaci F, Nappi G, Galli F, Manzoni GC, Calabresi P, Costa A. Migraine and psychiatric comorbidity: a review of clinical findings. J Headache Pain. 2011;12(2):115-25. https://doi.org/10.1007/s10194-010-0282-4
73. Gelaye B, Peterlin BL, Lemma S, Tesfaye M, Berhane Y, Williams MA. Migraine and psychiatric comorbidities among sub-saharan African adults. Headache. 2013;53(2):310-21. https://doi.org/10.1111/j.1526-4610.2012.02259.x
74. Jette N, Patten S, Williams J, Becker W, Wiebe S. Comorbidity of migraine and psychiatric disorders -- a national population-based study. Headache. 2008;48(4):501-16. https://doi.org/10.1111/j.1526-4610.2007.00993.x
75. Petkus AJ, Reynolds CA, Wetherell JL, Kremen WS, Gatz M. Temporal dynamics of cognitive performance and anxiety across older adulthood. Psychol Aging. 2017;32(3):278-92. https://doi.org/10.1037/pag0000164
76. Stillman AN, Rowe KC, Arndt S, Moser DJ. Anxious symptoms and cognitive function in non-demented older adults: an inverse relationship. Int J Geriatr Psychiatry. 2012;27(8):792-8. https://doi.org/10.1002/gps.2785