Multimodal Semantic Knowledge Assessment –Standard and Preliminary Data in Semantic Variant Primary Progressive Aphasia and Alzheimer's Disease in Comparison with Vascular Aphasia

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Multimodal Semantic Knowledge Assessment –Standard and Preliminary Data in Semantic Variant Primary Progressive Aphasia and Alzheimer's Disease in Comparison with Vascular Aphasia

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ABTRACT

Lexical-semantic disorders are known to be one of the major manifestations of aphasia, whether of vascular (as semantic aphasia -SA-) or degenerative (as semantic variant primary progressive aphasia -svPPA- and Alzheimer's disease -AD-) origin. In clinical practice, these disorders are mainly assessed by verbal tests, while, according to literature, the deficit must be observed in several modalities. The aim of this study was to create a French multimodal semantic assessment battery called EMCS (Évaluation Multimodale des Connaissances Sémantiques), which investigates, in a shorter time than the existing ones, semantic memory efficiency through several multimodal tasks.

Eighty-seven native French-speakers control participants were recruited. They underwent the 10 tasks from the EMCS battery, namely the verbal and non-verbal modalities. To explore the sensibility of the battery, three SA, two svPPA and two AD patients at the onset of the disease carried out the EMCS battery.

Statistical analyses led to establish normative data, with percentile scores, and highlighted, for controls, an effect of education level for the majority

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of the tests, an age effect for several tasks, but no gender effect. For every patient, results were discriminatory compared to the reference control group for several tasks, namely picture-naming, semantic knowledge about celebrities and taste subtest ($p < .05$).
The EMCS battery can contribute to identify, in a rather short amount of time, multimodal semantic disorders for patients suffering from vascular and degenerative aphasia. Thus, this tool may be a help for clinical diagnosis and offers the clinician the possibility to determine, at early stages, the nature of the semantic impairment (access or central).

Keywords: primary progressive aphasia; Alzheimer's disease; semantic knowledge assessment; multimodality

Évaluation multimodale des connaissances sémantiques – Données standards et préliminaires dans l'aphasie primaire progressive à variant sémantique et la maladie d'Alzheimer en comparaison avec l'aphasie vasculaire

RÉSUMÉ

Les troubles lexico-sémantiques sont connus pour être l'une des manifestations majeures de l'aphasie, qu'elle soit d'origine vasculaire (comme l'aphasie sémantique -AS-) ou dégénérative (comme l'aphasie sémantique progressive primaire -APPvs- et la maladie d'Alzheimer -MA-). En pratique clinique, ces troubles sont principalement évalués par des tests verbaux, alors que, selon la littérature, le déficit doit être observé dans plusieurs modalités. Le but de cette étude était de créer une batterie française d'évaluation sémantique multimodale appelée EMCS (Évaluation Multimodale des Connaissances Sémantiques), qui étudie, en un temps plus court que les outils existants, l'efficacité de la mémoire sémantique à travers plusieurs tâches multimodales.

Quatre-vingt-sept participants témoins français ont été recrutés. Ils ont subi les 10 tâches de la batterie EMCS, à savoir les modalités verbales et non verbales. Pour explorer la sensibilité de la batterie, trois patients AS, deux APPvs et deux MA au stade débutant de la maladie ont réalisé l'EMCS.

Analyses et résultats : Les analyses statistiques ont permis d'établir des données normatives, avec des scores en percentiles, et ont mis en évidence, pour les témoins, un effet du niveau d'éducation pour la majorité des tests, un effet d'âge pour plusieurs tâches, mais pas d'effet de sexe. Pour chaque patient, les résultats se sont montrés discriminants par rapport au groupe témoin de référence pour plusieurs tâches, à savoir la dénomination d'images, les connaissances sémantiques sur les célébrités et l'épreuve gustative ($p < 0,05$).

Discussion / Conclusion : La batterie EMCS peut contribuer à identifier, en un temps relativement court, des troubles sémantiques multimodaux chez des patients souffrant d'aphasie vasculaire et dégénérative. Ainsi, cet outil peut être une aide au diagnostic clinique et offre au clinicien la possibilité de déterminer, à un stade précoce, la nature de l'atteinte sémantique (accès ou centrale).

Mots clés : aphasie primaire progressive ; maladie d'Alzheimer ; évaluation des connaissances sémantiques ; multimodalité

INTRODUCTION

Aphasia is linked to a brain injury, primarily a stroke or a degenerative disease. This acquired language disorder can lead to lexical and semantic impairments.

As a reminder, semantic memory is a long-term memory storage corresponding to the context-free stoage of knowledge shared about the world, common to individuals of the same culture, and thus allows to assign meaning to names and objects' attributes, interpretation of sensory experiences, knowledge about people and facts (Chainay, 2005; Tulving, 1972). Semantic memory is also involved in the processing of unique entities, such as famous people (Gorno-Tempini & Price, 2001; Macoir et al., 2020). Semantic memory can be compared to a large encyclopedia (Chainay, 2005). This memory constitutes a basis for the use of language.

Several psycholinguistic variables can influence language production in particular in picture-naming of healthy individuals (Macoir & Lavoie, 2020); we will only mention those concerned in our study: i) semantic category: the picture-naming performance of natural objects is usually more affected than manufactured objects (Laws & Neve, 1999) ; ii) word frequency (i.e., the frequency of occurrence of a word): picture-naming latencies increase as word frequency decreases (Barry et al., 1997); iii) and imageability (i.e., the possibility to evoke a mental image from a word), which is easier for concrete words than for abstract words (Strain et al., 1995).

Semantic disorder leads to difficulties in naming objects and pictures in particular. Two main hypotheses have been suggested to explain semantic memory impairments (Shallice, 1988; Warrington & Shallice, 1984). One explanation claims loss of semantic information: semantic representations in memory decline gradually over time (i.e., degradation of semantic knowledge). A second hypothesis highlights that semantic deficits are due to difficulties in accessing or retrieving information stored in long-term semantic memory (i.e., difficulties accessing word knowledge). The cognitive bases of anomia correspond to a disorder of lexical access (difficulty in accessing the target word) or to a semantic representations disorder (difficulties to access or retrieve semantic features or loss of the semantic features constituting the concepts) (Gallant et al., 2019). Studies have highlighted atrophy or hypometabolism of the left anterior temporal lobe (Joubert et al., 2010) (involved in the processing of semantic knowledge), of the left temporo-parietal junction (Leyton et al., 2017)

(involved in lexical access) and of the left prefrontal cortex (Jefferies et al., 2008; Lambon Ralph et al., 2017) (involved in particular in semantic control processes).

According to the French National Institute of Health and Medical Research (Inserm, 2019), stroke is the leading cause of acquired disability in adults. Following a stroke, several language disorders associated with aphasia can occur, in particular semantic aphasia (SA), characterized by a pattern of multimodal semantic impairment with relatively intact conceptual knowledge but difficulty retrieving the relevant semantic information required by a task, i.e. semantic control.

The overall aging of the population is leading to an increase of people affected by neurodegenerative diseases, such as Alzheimer's disease and primary progressive aphasia (PPA). According to the World Health Organization (WHO), Alzheimer's disease is the most prevalent major neurocognitive disorder (Boccardi et al., 2017). Each year, more than seven million new cases are identified. This pathology affects around 36 million people worldwide. PPA identifies a rare group of neurodegenerative syndromes (around 5,000 cases in France) (Croisile et al., 2020), affecting the neural networks of language. This clinical syndrome can be classified into non-fluent/agrammatic, semantic and logopenic variants (Gorno-Tempini et al., 2011).

For several years, biological and imaging approaches have made it possible to establish a diagnosis of vascular disorders and dementia syndromes. However, clinical and cognitive assessment should not be neglected insofar as it provides key semiological and nosological elements (Delage et al., 2020).

Following a stroke, or during a memory consultation interview, patients and/or their relatives frequently express a language and/or memory complaint. SA is linked particularly to a semantic control impairment. Patients with SA usually present deficits in verbal and non-verbal semantic tasks as well as in other cognitive domains (Monetta et al., 2019). This pathology is associated with lesions in the prefrontal and temporo-parietal regions (Jefferies & Lambon Ralph, 2006; Lambon Ralph et al., 2017; Saygin et al., 2003).

Regarding neurodegenerative diseases, AD is characterized by a significant impairment in episodic memory from the initial stage of the disease (Dubois et al., 2007), but also by a deficit in semantic memory (Chainay, 2005; Delage et al., 2020). The lexico-semantic component is thus the most severely affected. Semantic disorder (i.e. degradation of semantic knowledge or difficulties accessing word knowledge) leads to poor performance in picture-naming, word-picture associations, and

semantic questionnaires (Macoir et al., 2014). Patients have difficulty naming familiar objects, biological entities (e.g. fruits, animals) and people. A concreteness effect is reported: patients are often more impaired in naming abstract words than concrete words (Joubert et al., 2017; Bechtold et al., 2021). These difficulties are the most frequent and the earliest symptoms of AD (Joubert et al., 2010; Laisney et al., 2011).

The core cognitive features of patients with svPPA are impaired picture-naming and single-word comprehension, these two criteria being essential for the diagnosis (Gorno-Tempini et al., 2011). Neuroimaging shows a bilateral anterior temporal atrophy, predominant in most cases in the left hemisphere (Gorno-Tempini et al., 2011). The word meaning impairment can extend beyond language with impaired face recognition, related to a predominant right atrophy, and difficulties in object knowledge (Busigny et al., 2009; Joubert et al., 2006; Montembeault et al., 2017; Snowden et al., 2004). A frequency effect (Gorno-Tempini et al., 2011) and a concreteness effect (Joubert et al., 2017) characterizes this pathology. But a reversal of the concreteness effect has also been reported, resulting of the degradation of visual feature knowledge (Macoir et al., 2009; Grossman et al., 2018). The concreteness effect is thus controversial. Therefore, a progressive loss of semantic knowledge characterizes AD and svPPA.

Semantic memory assessment is a real issue. However, in clinical practice, semantic knowledge is mainly assessed by verbal tests, while the criteria specify that the deficit must be observed in several modalities in order to determine a disorder of central origin (Henry et al., 2004; Monetta et al., 2019). To date, there are a few existing tests in French, such as the BECS-GRECO (Merck et al., 2011), the BETL (Tran & Godefroy, 2015), the GRETOP (Puel et al., 2016) and the QCS (questionnaire des connaissances sémantiques) (Simoes Loureiro & Lefebvre, 2016), but none of them allows a multimodal evaluation of semantic knowledge through all modalities, which are visual, verbal and sensory modalities. On the other hand, these tools involve a significant amount of time (Pollet et al., 2019), sometimes about more than two hours, over two sessions, like the BECS-GRECO.

The aim of this study was to create a French multimodal semantic assessment battery, which we called EMCS (Évaluation Multimodale des Connaissances Sémantiques). It investigates, in a shorter amount of time than the current available tools, semantic memory efficiency (access impairment and integrity of semantic knowledge) through several input

multimodal tasks (visual, verbal and sensory). This tool can allow clinicians to contribute to the differential diagnosis through the patient's performance on the EMCS subtests. Indeed, as specified before, patients with SA could show a disorder of lexical access (difficulty in accessing the target word) linked particularly to an impairment of semantic control. Patients with AD could have more difficulty naming biological entities than manufactured objects, abstract words than concrete words, and famous people. Patients with svPPA could show impairment with lower frequent words, abstract words (but a reversal of the concreteness effect could also be present). A progressive loss of semantic knowledge characterizes AD and svPPA, which is not the case in SA.

MATERIALS AND METHODS

Participants

Eighty-seven French control participants were recruited. Inclusion criteria for the study were 1) be French, 2) aged 50 and more, 3) Mini Mental Score Examination (MMSE) (Kalafat et al., 2003) score of 28/30 and 4) no history of neurological or psychiatric disorder, no cognitive complaint and 5) neither food allergies, swallowing disorders nor major uncorrected sensory disorders (especially visual or auditory).

Participants were selected according to three education levels: less than nine years of education (Level 1), between nine and eleven years of education (Level 2), and twelve years of education and above (Level 3). Two age groups were created: 50-64 years old and 65 years old and above (Tab. 1).

Table 1. Number of Control Participants Based on Independent Variables
Tableau 1. Nombre de participants contrôles concernant les variables indépendantes

Gender	Age	Level of education	Number of participants
Male (M)	50-64	1	6
		2	8
		3	8
	65	1	8
		2	8
		3	5
Total (M)			43
Female (F)	50-64	1	6
		2	7
		3	8
	65	1	8
		2	8
		3	7
Total (F)			44
Total			87

Note. Level 1 (less than nine years of education); level 2 (between nine and eleven years of education); level 3 (twelve years of education and more)

To explore the sensibility of the battery, patients with SA, AD and svPPA were recruited. Inclusion criteria for these participants were the following: 1) a diagnosis identified by a neurologist 2) this diagnosis confirmed by neuroimaging, 3) be French, 4) no food allergies, swallowing disorders, major uncorrected sensory disorders (especially visual or auditory) and no apraxia. Three SA, two svPPA and two AD patients at the onset of the disease (MMSE above 20/30) were recruited from different medical centers in France. These participants were aged from 52 to 71 years old, had between eight and fourteen years of education and were French.

All participants received an information letter explaining the purpose and procedure of the study. They agreed to take part in the study, which was approved by the ethics committee of University of Mons, Belgium.

Measures

All participants underwent the MMSE (Kalafat et al., 2003) and then the EMCS battery. Data was anonymized. A comprehensive cognitive assessment was administrated to all patients.

The EMCS includes three modalities: pictorial input modality (picture-naming, designation, semantic knowledge about celebrities); written words input modality (semantic association, semantic questionnaire, semantic odd word) and sensory input modality (auditory, tactile, olfactory and taste subtests) (Tab. 3 for a few examples). A computer with speakers is needed as subtests are presented on a PowerPoint document and one of them has an audio recording.

The semantic analysis of the first five subtests (picture-naming, designation, semantic association, semantic questionnaire, semantic odd word) of the EMCS is transversely oriented around eight common target words (six concrete and two abstract words of two syllables). These words are selected according to semantic category (three biological and three manufactured words) and frequency criteria (two nonfrequent words –between 0.00 and 10.00 occurrences per million–, two moderate frequent words –between 10.00 and 20.00 occurrences per million–, and four high frequent words –more than 20.00 occurrences per million–, New & Pallier, 2019): lavande (lavender), tracteur (tractor), collier (necklace), orange (orange), chemise (shirt), souris (mouse), odeur (smell), colère (anger). These psycholinguistic variables have been selected as they can influence the performance of individuals with acquired language disorder. The examiner, by comparing the performance for the same item across the different tasks, can conclude to a semantic knowledge impairment and therefore a central deficit (which is often shown in the previous stage of AD and characterizes svPPA), when the participant gives a wrong answer on several tasks for the same item. Otherwise, he will conclude to an access disorder (inconstant errors), language features of SA. A table has been created to visualize the errors in a synthetic way and allow the clinician to establish a diagnosis (Tab. 2).

Table 2. Analysis of the Nature of the Lexico-Semantic Disorder (access/central)
Tableau 2. Analyse de la nature du trouble lexico-sémantique (d'accès/central)

	Pictorial input modality		Written words input modality		
	Picture-naming	Designation	Semantic association	Semantic questionnaire	Semantic odd word
Lavender					
Tractor					
Necklace					
Orange					
Shirt					
Mouse					
Smell					
Anger					

Each subtest is assessed on eight points. Thus, for several subtests (semantic association, semantic questionnaire, semantic odd word, semantic knowledge about celebrities, a proportion must be carried out to reduce the score to eight. The three modalities are assessed on 24 points each, with a total score of 72. An Excel® table is used to calculate the scores of each subtest, for the three modalities as well as the total score. The clinician also has a roadmap to guide him through the subtests' assessment.

The EMCS is administered in the following order:

1. **Picture-naming** (pictorial input modality): the participant is asked to name eight pictures presented on a computer screen. A correct answer is given one point. This subtest is assessed on eight points.

2. **Designation** (pictorial input modality): the participant must point to the corresponding image among several distractors: neutral, near and far semantics. One point is given for a correct designation. This subtest is assessed on eight points.

3. **Semantic association** (written words input modality): the participant has to match a written target word with a word from the same semantic field. One point is allocated for a correct match. This subtest is assessed on 48 points.

4. **Semantic questionnaire** (written words input modality): this subtest is based on the eight target words of reference. For each of them, the participant has to answer to six questions (implying a forced "yes" or "no" answer). One point is given for a correct answer. This subtest is assessed on 48 points.

5. **Semantic odd word** (written words input modality): for each of the target words, three lists of written odd words at a subordinate, ordered and supra-ordered level are presented. This distribution should be considered during the quantitative and qualitative analysis of the ECCS. A rating grid is proposed in order to determine the level of semantic impairment. Thus, each of the semantic levels (sub-ordered, ordered and supra-ordered) equals to eight points. One point is given for a correct answer. This subtest is assessed on 24 points.

6. **Semantic knowledge about celebrities** (pictorial input modality): pictures of famous people are shown to the participant, who has to say whether the target face is familiar and give the name and surname of the person corresponding to the face. In the absence of a given name and/or surname, the examiner gives the profession of the celebrity (which has been described in the literature (Bruce & Young, 1986) as a potential facilitating effect). Half a point is then awarded for each item named after facilitation. The participant must then provide two semantic information. This subtest is assessed on 24 points.

The following subtests are evaluated on six points, with a total score of 24. The participant must close their eyes, then name orally what they hear, touch, smell or taste. One point and a half are awarded for each correct oral answer. When the answer is incorrect, a designation among four pictures, including near and far semantic distractors, is proposed. If the answer is correct after facilitation, half a point is awarded.

7. **Auditory subtest** (sensory input modality): the participant has to name four sounds he listened: coq (rooster), téléphone (telephone), abeille (bee), voiture (car).

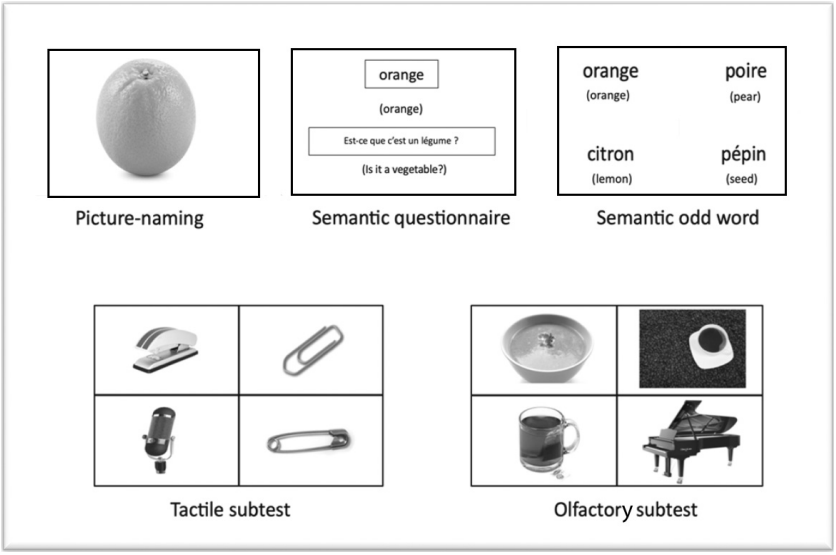
8. **Tactile subtest** (sensory input modality): the participant has to name four objects he touched: trombone (paper clip), feuille de papier (sheet of paper), doigt (finger), riz (rice).

9. **Olfactory subtest** (sensory input modality): the participant has to name four objects he smelled: café (coffee), cannelle (cinnamon), parfum (perfume), marqueur (marker).

10. **Taste subtest** (sensory input modality): the participant has to name four objects he tasted: vanille (vanilla), sirop de pêche (peach syrup), lait (milk), sirop de menthe (mint syrup).

The completion time for the entire protocol is 30 minutes for healthy participants and about 40 to 45 minutes for patients.

Table 3. Subtests Examples
Tableau 3. Exemples de sous-tests



Statistical analyses

Statistical analyses were conducted with Excel ® and JASP ®. A p value < .05 was adopted to determine statistical significance. Normality was tested using the Shapiro-Wilk test. Data demonstrated non-normal distributions (W = 0,98; p = 0,04). Thus, group comparisons of demographic data (age, gender, education level) have been carried out with the non-parametric Kruskal-Wallis test. Patients' scores of were analyzed with the sample t-test (Crawford et al., 2009), which allowed to calculate the precise position of each patient in relation to their small reference control group. The percentile ranks method was used, as it represents for many clinicians one of the best approaches for neuropsychological norms (Turcotte et al., 2018). Cut-off scores for impairment were set at the 5th percentile.

RESULTS

Regarding control participants, statistical analyses highlighted an effect of education level for the majority of the subtests. Only the semantic questionnaire subtest did not show any significance of education level

(p = .09). The Kruskal-Wallis test also showed an age effect for several tasks ($p < .05$): picture-naming (p = .04), designation (p = .02), semantic questionnaire (p = .04), semantic odd word (p = .001), tactile ($p < .001$) and taste (p = .03) subtests. Analyses showed no gender effect. Indeed, the Kruskal-Wallis test did not show a significant difference between men's and women's performances on the EMCS battery (p = .28). Thus, normative data were established on education level and age. Six groups were created, distributed according to age and level of education (Tab. 4).

Table 4. Distribution of the six Control Groups
Tableau 4. Distribution des six groupes contrôles

Control groups (CG)	Age and level of education	Number of participants
CG1	50-64, L1	12
CG2	50-64, L2	15
CG3	50-64, L3	16
CG4	65, L1	16
CG5	65, L2	16
CG6	65, L3	12

Note. Level 1 (less than nine years of education); level 2 (between nine and eleven years of education); level 3 (twelve years of education and more)

Normative data are presented with percentile scores for each subtest, for the scores of the three modalities and for the global score. Table 5 summarizes normative data with percentiles for all groups for EMCS total and for the three modalities.

Table 5. Normative Data with Percentiles for Total Score and for the Three Modalities of EMCS Battery (5th Percentile represents cut-off Scores for Impairment)
Tableau 5. Données normatives en percentiles des scores totaux et des trois modalités de la batterie EMCS (le percentile 5 représente les scoes seuils)

Age Level	GC 1=12 50-64 1	GC 2=15 50-64 2	GC 3=16 50-64 3	GC 4=16 65 et + 1	GC 5=16 65 et + 2	GC 6=12 65 et + 3
EMCS Total /72						
Centile 5	55,32	59,70	65,98	54,48	58,17	61,46
Centile 10	55,59	59,78	66,29	54,67	58,63	61,89
Centile 25	56,54	59,96	66,88	55,25	59,63	63,29
Centile 50	57,13	62,58	68,50	56,71	61,38	64,04

Centile 75	58,42	63,83	70,17	57,77	61,69	64,29
Centile 90	58,74	65,10	70,46	59,83	62,00	65,27
Centile 95	59,46	66,14	70,77	61,00	62,27	65,56
EMCS Pictorial input modality /24						
Centile 5	18,03	19,90	22,58	17,83	19,29	21,52
Centile 10	18,33	20,13	22,83	18,00	19,83	21,70
Centile 25	18,58	21,42	23,00	18,79	20,13	22,13
Centile 50	19,33	22,00	23,33	20,33	21,25	22,67
Centile 75	20,67	23,33	24,00	20,83	22,04	22,75
Centile 90	20,67	23,53	24,00	21,33	23,33	23,00
Centile 95	20,97	23,67	24,00	21,67	23,46	23,15
EMCS Written words input modality /24						
Centile 5	19,79	20,90	22,92	19,17	21,04	21,85
Centile 10	20,22	21,13	23,17	19,83	21,25	22,00
Centile 25	20,67	22,00	23,33	20,33	21,33	22,25
Centile 50	21,00	22,33	23,50	20,50	21,58	23,08
Centile 75	21,75	23,08	23,67	21,42	22,21	23,33
Centile 90	22,15	23,33	23,67	21,83	22,75	23,48
Centile 95	22,24	23,43	23,75	22,04	23,13	23,58
EMCS Sensory input modality /24						
Centile 5	14,33	14,78	19,31	14,06	15,56	16,50
Centile 10	15,08	15,30	19,88	14,63	15,75	16,58
Centile 25	15,75	16,88	20,25	15,00	16,31	17,81
Centile 50	16,50	18,00	22,13	16,13	17,63	18,75
Centile 75	17,44	19,50	22,69	17,44	18,38	19,50
Centile 90	18,00	19,50	24,00	18,75	19,88	19,50
Centile 95	19,35	20,18	24,00	19,88	20,25	19,84

Note. Level 1 (less than nine years of education); level 2 (between nine and eleven years of education); level 3 (twelve years of education and more)

All patients scored lower than controls for the global score and for the total score of the three input modalities, except for written words input modality, for which the two patients with AD showed preserved performances ($p > .05$). Concerning the subtests, for every patient, results were discriminatory compared to the reference control group for picture-naming, semantic knowledge about celebrities and taste subtest, with significantly impaired scores. Only the

auditory subtest did not show a significant impairment for all the patients compared to healthy participants. Table 6 summarizes the sociodemographic characteristics of the patients as well as their scores at the eight subtests (and the different error types and the number of each error type), at the different modalities and at global test.

Table 6. Sociodemographic Characteristics, Results and Error Types of the Patients
Tableau 6. Caractéristiques sociodémographiques, résultats et types d'erreurs des patients

Input modality	Subtest	AD-X. 71 ans, L3 AD, MMS 21/30	AD-V. 71 ans, L1 AD MMS 21/30	PPA-Y. 71 ans, L3 svPPA MMS 21/30	PPA-W. 68 ans, L1 svPPA MMS 21/30	SA-J. 52 ans, L3 SA	SA-M. 53 ans, L3 SA	SA-D. 54 ans, L2 SA
	Naming/8	6*	4*	4*	5	5***	4***	3**
	Error type	1 SP	1 SP	1 SP-1 AP	1 SP	1 VSP-1 SSP-	3 VSP	3 VSP-1 AP- 1 SSP
	NIF%	25	50	50	37,5	1 AP 37,5	50	62,5
Pictorial	Designation/8	8	7	8	6*	8	7**	5
	Error type		1 SP		1 SP		1 AE	1 AE
	NIF%	0	12,5	0	25	0	12,5	37,5
	Celebrities/8	6*	2*	5,5***	4*	6***	3***	4***
	NIF%	25	75	31,25	50	25	62,5	50
	TOTAL/24	**20***	**13***	**17,5***	**15***	**19*****	**14*****	**12*****
	NIF%	16,6	45,8	27,08	37,5	20,8	41,6	50
	Semantic association/8	8	8	7	4***	6	7	5***
	NIF%	0	0	12,5	50	25	12,5	37,5
Written words	Semantic questionnaire/8	8	7	7	6***	7***	6***	6***
	NIF%	0	12,5	12,5	25	12,5	25	25
	Semantic odd word	6	6	6	4	6***	5***	5*
	NIF%	25	25	25	50	25	37,5	37,5
	TOTAL/24	**22**	**21**	**20***	**14*****	**19*****	**18*****	**16*****
	NIF%	8,3	12,5	16,6	41,6	20,8	25	33,3
	Auditory/6	4	4,5	4	6	6	4,5	4,5
	Error type		1 SP	1 SP-1 AP			3 VSP	2 SP
	NIF%	33,3	25	33,3	0	0	25	25

Sensory	Tactile/6	4	1,5**	5	5	4,5***	4,5***	3***
	Error type	1 SP		1 SP				1 AP
	NIF%	33,3	75	16,6	16,6	25	25	50
	Olfactory/6	3	1,5*	2*	2*	2**	4	2
	Error type							1 SP
	NIF%	50	75	66,6	66,6	66,6	33,3	66,6
	Taste/6	2*	1,5**	0,5**	3*	2***	4,5	3
	Error type	1 SP	1 SP			1 VSP		
	NIF%	66,6	75	91,6	50	66,6	25	50
	TOTAL/24	**13***	**9****	**11,5***	**16***	**14,5*****	**17.5****	**12.5***
	NIF%	45,8	62,5	52,02	33,3	39,5	27,07	47,9
	TOTAL /72	**55***	**43***	**49***	**45***	**52,5*****	**49,5*****	**40,5*****

Note. *: p <.05; **: p <.01; ***: p <.001 – Error type: SP: semantic paraphasia; VSP: visuo-semantic paraphasia; AP: adapted paraphrase; AE: associative error; SSP: superordinate semantic paraphasia; NIF%: percentage of number of failed items

Qualitative analyses showed several similarities and differences between patients. First, they revealed similar errors for SA and neurodegenerative patients, with semantic (e.g., camion- truck- instead of tracteur-tractor), visuo-semantic (e.g., citron-lemon pour orange-orange) paraphasias, superordinate semantic paraphasias (e.g., fleur-flower for lavande-lavander) and adapted paraphrases (e.g., fleur violette- purple flower- for lavande-lavander; engin qui se met en route- machine moving- for tracteur-tractor) in picture-naming and sensory modality subtests, in particular auditory and tactile subtests. The errors concerned words of different frequencies. Conversely, associative errors were only noted for patients with SA (e.g., flacon de parfum-perfume bottle instead of odeur-smell for designation subtest).

Then, qualitative analyses highlighted constant errors for semantic association, semantic questionnaire, semantic odd word subtests, with wrong answers on several tasks for the same item, for patients with AD and svPPA, except for one patient. For example, for the item "colère" (anger), a patient with AD provided incorrect answers for the semantic questionnaire, the semantic odd word in written words input modality and the semantic association of written words subtests. For the item "collier" (necklace), he produced errors in the picture-naming, the semantic odd word in written words input modality and the semantic association of written words subtests.

By comparing the performance for the same item in the different subtests, analyses reported that patients with SA produced inconstant errors:

an item failed in one or several tasks was successful in other subtests. A patient in particular produced the following errors: for the item "odeur" (smell), he failed the semantic questionnaire subtest and the semantic odd word in written words input modality subtest but he succeeded the semantic association of written words subtest. For the item "souris" (mouse), the same patient failed the semantic questionnaire subtest but succeeded the semantic association of written words subtest and the semantic odd word in written words input modality subtest. These inconstant errors were found for five items out of the eight ones presented.

Regarding concreteness effect, abstract items didn't appear to be more impaired than the concrete ones for SA patients. However, this result has to be carefully considered, as our test comprises only two abstract items. Conversely, patients with AD provided more errors on abstract items than on concrete ones. Finally, patients with svPPA also gave incorrect answers for both abstract items (odeur -smell- and colère -anger).

DISCUSSION

Contribution of the study

This study presents a multimodal semantic knowledge assessment tool, which was developed to investigate, in a shorter amount of time than the existing batteries, semantic memory efficiency. Therefore, the EMCS battery targets several multimodalities.

This tool offers normative data for persons of fifty years old and older. Among the socio-demographic variables studied, it appears that education level and age significantly influence the performance of control participants on the EMCS. This means that subjects with the lowest education level and older subjects score lower on the EMCS subtests. More precisely, results were able to demonstrate an education level effect on performances in the majority of EMCS subtests: picture-naming, designation, semantic association, semantic odd word, semantic knowledge about celebrities, tactile, olfactory and taste tasks. These results are in accordance with the literature. Education level has an impact on lexical-semantic diversity, and more broadly on semantic memory (Merck et al., 2011). A lower level of education can translate fewer opportunities to enrich the content of semantic memory (da Silva et al., 2004; Gudayol-Ferré et al., 2008). An age effect is reported for several tasks, which also supports

several studies (Nyberg et al., 2003; Giffard et al., 2001). However, it is important to highlight that, according to other studies, semantic knowledge is preserved in normal aging (Desgranges et al., 1994; Park et al., 2002; Toepper, 2017). This would result from a lexical recovery which slower with age (Eustache et al., 1998) and a less efficient semantic control (Hoffman, 2019). Finally, statistical analyses do not show any effect of gender on the performance of this group, as described in the literature (Tran & Godefroy, 2011).

Statistical analyses highlighted that all patients scored lower than controls. Concerning the subtests, for every patient, results were discriminatory compared to the reference control group for picture-naming, semantic knowledge about celebrities and taste subtest, with significantly impaired scores. Only the auditory subtest did not show a significant impairment for all the patients compared to healthy participants. Wrong answers concerned all modalities, for both clinical populations (that is vascular and neurodegenerative diseases), as reported in recent studies (Jefferies & Lambon Ralph, 2006; Joubert et al., 2017). For SA patients, the semantic questionnaire and the semantic odd word subtests showed greater impaired performances than the designation tasks. In other words, subtests requiring greater semantic control are more impaired compared to the ones in which the level of required semantic control is lower (Corbett et al., 2009). Indeed, these tasks require more attention since they involve precisely to select the relevant characteristics of the item and inhibiting the ones that are not. This conclusion can be compared with the executive functions impairment that the three patients exhibited. The cognitive assessment had revealed in particular a flexibility impairment for a one patient and, in addition, an inhibition impairment for the two other patients. Several studies report correlations between executive dysfunction and patients with SA performances on semantic tests (Corbett et al., 2009; Thompson et al., 2018). Despite the absence of a statistical correlation analysis between these functions in our study, the hypothesis of a semantic control deficit, called by Jefferies et al. (2008) executive control in semantic cognition, is however confirmed by the results of the quantitative analysis of the patients.

Qualitative analyses revealed that every patient evaluated in this study produced semantic paraphasias and adapted periphrases. These results confirm a lexical-semantic disorder for clinical populations (Tran, 2012, 2018). More specifically, for patients with SA, the presence of adapted periphrases indicates that the concept is not lost but that the patient does not have access to it when performing the subtest (Corbett et al., 2009). Regarding patients with svPPA and AD, this type of errors can be

explained by the gradual degradation of semantic knowledge (Tran et al., 2012). Indeed, the four patients were at the early stages of the disease. Therefore, conceptual knowledge can be partially altered (Joubert et al., 2010; Verma & Howard, 2012).

Qualitative analyses highlighted constant errors for patients with AD and svPPA, indicating a semantic knowledge impairment, and therefore a central deficit. This plurimodal impairment shows a semantic knowledge impairment (Tran et al., 2012), in accordance with amodal semantic deficits by an alteration of the "hub", a convergence zone in which the different semantic features of a concept (the spokes), required to accomplish a task, are linked together (Chiou & Lambon Ralph, 2019). The results of a patient with svPPA did not show any semantic alteration in sensory modalities. This patient was at the early stage of the disease. As the degradation of the semantic stock is progressive (Gorno-Tempini et al., 2011; Tee & Gorno-Tempini, 2019), some knowledge can be preserved.

Patients with SA produced inconstant errors: an item failed in one or several tasks was successful in other subtests. We conclude that there is no multimodal deficit and that patients with SA present an access disorder, which agrees with the conclusions of Jefferies and Lambon Ralph (2006): the semantic questionnaire subtest, the semantic odd word in written words input modality subtest and the semantic association of written words subtest require a more consequent semantic control compared to tests such as the naming on images or on auditory input. Thus, performance varies according to the executive demand of the tests: the degree of constancy of performance is correlated with the executive control required for the task and does not seem to depend on the modality (de Partz de Courtray, 2016). The quantitative (scores for EMCS) and qualitative (category, frequency, concreteness effects, access (with inconstant errors: an item failed in one or several tasks was successful in other subtests) vs central (with constant errors: wrong answers on several tasks for the same item) impairment) analyses made it possible to characterize more precisely the nature of the lexical-semantic disorder. These analyses are in accordance with the data in the literature and make it possible to hypothesize a deficit in the regulation of semantic processing, also called semantic control impairment.

Concerning the nature of this semantic impairment, the errors concerned words of different frequencies for the patients with SA. This absence of a frequency effect for the three types of patients are not reported in the literature (Gertel et al., 2020; Gorno-Tempini et al., 2011). This can be due to the small number of patients evaluated.

Associative errors were observed for the SA patients. For example, two of them selected the perfume bottle when they were asked to point to the item "odeur" (smell). This type of error supports the hypothesis of an executive deficit underlying the semantic impairment: patients fail to inhibit the strong semantic association between the concept and the distractors. These semantic associations emphasize, on one hand, that the word is not lost, and, on the other hand, that the relevant aspects of the word have not been wisely selected to designate the correct answer. This inaccurate selection would result from a lack of semantic control (Humphreys & Forde, 2005; Noonan et al., 2013). Patients with AD and svPPA did not produce these errors.

Finally, the EMCS highlighted those patients with AD and svPPA gave incorrect answers for abstract items. Even if a concreteness effect has to be taken with caution due to the small number of abstract items, these results are in line with the literature data which report that the presence of this concreteness effect in patients with AD and with svPPA confirms the degradation of conceptual knowledge (Hoffman et al., 2013; Joubert et al., 2017). According to these authors, concrete words are more anchored as their representations are richer and more detailed than abstract words. In our study, the reversal of the concreteness effect has not been observed in patients with svPPA.

To conclude, the quantitative and qualitative analyses of the two populations performances' help to characterize the semantic disorder for each of them. Thus, the EMCS battery allows the assessment of semantic knowledge in a short amount of time, with verbal, visual, auditory, olfactory, tactile and taste modalities. With quantitative but also qualitative analyses, this tool made it possible to identify the nature of semantic impairment. The EMCS battery can reveal an access disorder, linked to a deficit in semantic control (unimodal disorder), which characterizes SA (Jefferies et al., 2018), and a central impairment of semantic knowledge, frequent in svPPA and AD patients (multimodal disorder).

The EMCS battery provides a help in the development of care, which must be implemented as early as possible, especially for patients with svPPA (Gravel-Laflamme et al., 2012; Teichmann, 2019). Indeed, clinicians will be able to rely on the preserved modalities.

Limitations and perspectives

The main limitation concerns the clinical population. Indeed, as it is a very small sample, carrying out between-groups comparisons was difficult. Another limitation is that the taste subtest of the EMCS battery

cannot always be assessed in the post-stroke aphasic population because of swallowing disorders. Thus, for this work, several patients corresponding to the profile could not be included in the study because of their dysphagia.

We have several perspectives: increase the number of participants, investigate the convergent validity of the tool and test its specificity and its test-retest reliability.

CONCLUSION

The current study highlights the clinical benefit of the EMCS battery, which provides a unique contribution to semantic assessment tools, with a more thorough semantic knowledge assessment. The EMCS battery identifies, in a shorter amount of time than the existing tools, with quantitative and qualitative analyses the semantic disorder (unimodal or multimodal) in SA, svPPA and AD. Evaluating semantic memory across all modalities is useful for clinicians to better define the therapeutic project.

REFERENCES

Almaghyuli, A., Thompson, H., Lambon Ralph, M. A., & Jefferies, E. (2012). Deficits of semantic control produce absent or reverse frequency effects in comprehension: Evidence from neuropsychology and dual task methodology. *Neuropsychologia*, *50*(8), 1968-1979. https://doi.org/10.1016/j.neuropsychologia.2012.04.022

Barry, C., Morrison, C. M., & Ellis, A. W. (1997). Naming the Snodgrass and Vanderwart pictures: Effects of age of acquisition, frequency, and name agreement. *The Quarterly Journal of Experimental Psychology: Section A*, *50*(3), 560-585.

Bechtold, L., Bellebaum, C., Hoffman, P., & Ghio, M. (2021). Corroborating behavioral evidence for the interplay of representational richness and semantic control in semantic word processing. *Scientific reports*, *11*(1), 6184. https://doi.org/10.1038/s41598-021-85711-7

Boccardi, V., Comanducci, C., Baroni, M., & Mecocci, P. (2017). Of Energy and Entropy: The Ineluctable Impact of Aging in Old Age Dementia. *International journal of molecular sciences*, *18*(12), 2672. https://doi.org/10.3390/ijms18122672

Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology*, *77*(3), 305-327. https://doi.org/10.1111/j.2044- 8295. 1986.tb02199.x

Busigny, T., Robaye, L., Dricot, L., & Rossion, B. (2009). Right anterior temporal lobe atrophy and person-based semantic defect: a detailed case study. *Neurocase*, *15*(6), 485–508, https://doi.org/10.1080/13554790902971141

Chainay, H. (2005). Déficit de la mémoire sémantique dans la démence de type Alzheimer. In A-M. Ergis, M.-C. Gély-Nargeot, M. Van der Linden (dir.), *Les troubles de la mémoire dans la maladie d'alzheimer*, Paris, Solal, 147-171.

Chiou, R., & Lambon Ralph, M. A. (2019). Unveiling the dynamic interplay between the hub- and spoke-components of the brain's semantic system and its impact on human behaviour. *NeuroImage*, *199*, 114-126. https://doi.org/10.1016/j.neuroimage.2019.05.059

Corbett, F., Jefferies, E., Ehsan, S., & Lambon Ralph, M. A. (2009). Different impairments of semantic cognition in semantic dementia and semantic aphasia: Evidence from the non-verbal domain. *Brain: A Journal of Neurology*, *132*, 2593-2608.https://doi.org/10.1093/brain/awp146

Crawford, J. R., Garthwaite, P. H., & Howell, D. C. (2009). On comparing a single case with a control sample: an alternative perspective. *Neuropsychologia*, *47*(13), 2690–2695. https://doi.org/10.1016/j.neuropsychologia.2009.04.011

Croisile, B., Basaglia-Pappas, S., Laurent, B., Lefebvre, L., Renard A. (2020). Les aphasies primaires progressives : Du diagnostic à la prise en charge. *Neurologies, 23*(225), *56-68.*

da Silva, C. G., Petersson, K. M., Faísca, L., Ingvar, M., & Reis, A. (2004). The effects of literacy and education on the quantitative and qualitative aspects of semantic verbal fluency. *Journal of Clinical and Experimental Neuropsychology*, *26*(2), 266-277. https://doi.org/10.1076/jcen.26.2.266.28089

Desgranges, B., Eustache, F., & Rioux, P. (1994). Effets de l'âge et du niveau d'étude sur différents sous-systèmes mnésiques. *L'Année psychologique*, *94*(3), 345-367. https://doi.org/10.3406/psy.1994.28768

de Partz de Courtray, M.-P. (2016). Traitements des troubles de la production orale des mots : Composantes sémantique et lexicale. In X. Seron & M. Van der Linden, *Traité de neuropsychologie clinique de l'adulte – Revalidation (Tome 2)*, (2nd ed, p. 161-188), Paris, De Boeck/Solal.

Delage, É., Rouleau, I., Barbeau, E., & Joubert, S. (2020). Les troubles sémantiques au stade prodromal de la maladie d'Alzheimer. *Revue de neuropsychologie*, *12*(3), 290-298, doi :10.1684/nrp.2020.0587

Dubois, B., Feldman, H. H., Jacova, C., Dekosky, S. T., Barberger-Gateau, P., Cummings, J., Delacourte, A., Galasko, D., Gauthier, S., Jicha, G., Meguro, K., O'brien, J., Pasquier, F., Robert, P., Rossor, M., Salloway, S., Stern, Y., Visser, P. J., & Scheltens, P. (2007). Research criteria for the diagnosis of Alzheimer's disease: revising the NINCDS-ADRDA criteria. *The Lancet. Neurology*, *6*(8), 734-746. https://doi.org/10.1016/S1474-4422(07)70178-3

Eustache, F., Desgranges, B., Jacques, V., & Platel, H. (1998). Preservation of the attribute knowledge of concepts in normal aging groups. *Perceptual and Motor Skills*, *87*, 1155-1162. https://doi.org/10.2466/pms.1998.87.3f.1155

Gallant, M., Lavoie, M., Hudon, C., & Monetta, L. (2019). Analysis of Naming Errors in Healthy Aging, Mild Cognitive Impairment, and Alzheimer's Disease. *Canadian Journal of Speech-Language Pathology & Audiology*, *43*(2).

Gorno-Tempini, M. L., Hillis, A. E., Weintraub, S., Kertesz, A., Mendez, M., Cappa, S. F., Ogar, J. M., Rohrer, J. D., Black, S., Boeve, B. F., Manes, F., Dronkers, N. F., Vandenberghe, R., Rascovsky, K., Patterson, K., Miller, B. L., Knopman, D. S.,

Hodges, J. R., Mesulam, M. M., & Grossman, M. (2011). Classification of primary progressive aphasia and its variants. *Neurology*, *76*(11), 1006-1014. https://doi.org/10.1212/WNL.0b013e31821103e6

Gorno-Tempini, M. L., & Price, C. J. (2001). Identification of famous faces and buildings: a functional neuroimaging study of semantically unique items. *Brain : a journal of neurology*, *124*, 2087-2097. https://doi.org/10.1093/brain/124.10.2087

Gravel-Laflamme, K., Routhier, S., & Macoir, J. (2012). Les approches thérapeutiques non pharmacologiques des troubles du langage dans la démence sémantique [Non-pharmacological therapies of language deficits in semantic dementia]. *Geriatrie et psychologie neuropsychiatrie du vieillissement*, *10*(4), 427-436.https://doi.org/10.1684/pnv.2012.0368

Grossman, M., & Irwin, D. J. (2018). Primary Progressive Aphasia and Stroke Aphasia. *Continuum*, *24*(3), 745-767. https://doi.org/10.1212/CON.0000000000000618

Gudayol-Ferré, E., Lara, J. P., Herrera-Guzman, I., Böhm, P., Rodés, E., Ansaldo, A. I., & Peña-Casanova, J. (2008). Semantic memory as assessed by the Pyramids and Palm Trees Test : The impact of sociodemographic factors in a Spanish-speaking population. *Journal of the International Neuropsychological Society*, *14*(1), 148-151. https://doi.org/10.1017/S1355617708080168

Hoffman, P., Jones, R. W., & Lambon Ralph, M. A. (2013). Be concrete to be comprehended: consistent imageability effects in semantic dementia for nouns, verbs, synonyms and associates. *Cortex; a journal devoted to the study of the nervous system and behavior*, *49*(5), 1206-1218. https://doi.org/10.1016/j.cortex.2012.05.007

Hoffman, P. (2019). Divergent effects of healthy ageing on semantic knowledge and control: Evidence from novel comparisons with semantically impaired patients. *Journal of Neuropsychology*, *13*(3), 462-484. https://doi.org/10.1111/jnp.12159

Humphreys, G. W., & Forde, E. M. E. (2005). Naming a giraffe but not an animal: Base-level but not superordinate naming in a patient with impaired semantics. *Cognitive Neuropsychology*, *22*(5), 539-558. https://doi.org/10.1080/02643290442000176

Inserm. (2019). *Accident vasculaire cérébral (AVC)*. Inserm – La science pour la santé. https://www.inserm.fr/information-en-sante/dossiers-information/accident-vasculaire-cerebral-avc

Jefferies, E., & Lambon Ralph, M. A. (2006). Semantic impairment in stroke aphasia versus semantic dementia: A case-series comparison. *Brain: A Journal of Neurology*, *129*, 2132-2147. https://doi.org/10.1093/brain/awl153

Jefferies, E., Patterson, K., & Ralph, M. A. (2008). Deficits of knowledge versus executive control in semantic cognition: insights from cued naming. *Neuropsychologia*, *46*(2), 649-658. https://doi.org/10.1016/j.neuropsychologia.2007.09.007

Joubert, S., Brambati, S. M., Ansado, J., Barbeau, E. J., Felician, O., Didic, M., Lacombe, J., Goldstein, R., Chayer, C., & Kergoat, M. J. (2010). The cognitive and neural expression of semantic memory impairment in mild cognitive impairment and early Alzheimer's disease. *Neuropsychologia*, *48*(4), 978-988.https://doi.org/10.1016/j.neuropsychologia.2009.11.019

Joubert, S., Felician, O., Barbeau, E., Ranjeva, J. P., Christophe, M., Didic, M., Poncet, M., & Ceccaldi, M. (2006). The right temporal lobe variant of frontotemporal dementia: cognitive and neuroanatomical profile of three patients. *Journal of neurology*, *253*(11), 1447-1458. https://doi.org/10.1007/s00415-006-0232-x

Kalafat, M., Hugonot-Diener, L., & Poitrenaud, J. (2003). Standardisation et étalonnage français du « Mini Mental State »

(MMS) version GRECO. *Revue de neuropsychologie*, *13*(2), 209-236.

Laisney, M., Giffard, B., Belliard, S., de la Sayette, V., Desgranges, B., & Eustache, F. (2011). When the zebra loses its stripes: Semantic priming in early Alzheimer's disease and semantic dementia. *Cortex; a journal devoted to the study of the nervous system and behavior*, *47*(1), 35-46. https://doi.org/10.1016/j.cortex.2009.11.001

Lambon Ralph, M. A., Jefferies, E., Patterson, K., & Rogers, T. T. (2017). The neural and computational bases of semantic cognition. *Nature Reviews. Neuroscience*, *18*(1), 42-55. https://doi.org/10.1038/nrn.2016.150

Laws, K. R., & Neve, C. (1999). A normal category-specific advantage for naming living things. *Neuropsychologia*, *37*(11), 1263-1269. https://doi.org/10.1016/s0028-3932(99)00018-4

Leyton, C. E., Hodges, J. R., Piguet, O., & Ballard, K. J. (2017). Common and divergent neural correlates of anomia in amnestic and logopenic presentations of Alzheimer's disease. *Cortex; a journal devoted to the study of the nervous system and behavior*, *86*, 45-54. https://doi.org/10.1016/j.cortex.2016.10.019

Macoir J. (2009). Is a plum a memory problem? Longitudinal study of the reversal of concreteness effect in a patient with semantic dementia. *Neuropsychologia*, *47*(2), 518-535. https://doi.org/10.1016/j.neuropsychologia.2008.10.006

Macoir, J., Laforce, R. J., Monetta, L., & Wilson, M. (2014). Les troubles du langage dans les principales formes de démence et dans les aphasies primaires progressives : Mise à jour à la lumière des nouveaux critères diagnostiques. *Gériatrie et Psychologie Neuropsychiatrie du Vieillissement*, *12*(2), 199-208. https://doi.org/10.1684/pnv.2014.0466

Macoir, J., & Lavoie, M. (2020). Naming and anomia. *Reference Module in Neuroscience and Biobehavioral Psychology*. https://doi.org/10.1016/B978-0-12-819641-0.00035-9

Macoir, J., Pilote-Paradis, S., Lacoste, L., Proulx, M., & Auclair-Ouellet, N. (2020). Of logos and men: semantic memory impairment for unique entities in a case of semantic variant of primary progressive aphasia. *Neurocase*, *26*(4), 188-196. https://doi.org/10.1080/13554794.2020.1772311

Merck, C., Charnallet, A., Auriacombe, S., Belliard, S., Hahn-Barma, V., Kremin, H., … & Siegwart, H. (2011). La batterie d'évaluation des connaissances sémantiques du GRECO (BECS-GRECO) : validation et données normatives. *Revue de neuropsychologie*, *3*(4), 235-255. https://doi.org/10.1684/nrp.2011.0194

Monetta, L., Légaré, A., Macoir, J., & Wilson, M. A. (2019). Questionnaire Sémantique de Québec (QueSQ). Développement, validation et normalisation. *Canadian Journal on Aging = La Revue Canadienne Du Vieillissement*, 1-9. https://doi.org/10.1017/S0714980819000333

Montembeault, M., Brambati, S. M., Joubert, S., Boukadi, M., Chapleau, M., Laforce, R. J., Wilson, M. A., Macoir, J., & Rouleau, I. (2017). Naming unique entities in the semantic variant of primary progressive aphasia and Alzheimer's disease: Towards a better understanding of the semantic impairment. *Neuropsychologia*, *95*, 11-20. https://doi.org/10.1016/j.neuropsychologia.2016.12.009

New, B., & Pallier, C. (2019). *Lexique*. http://www.lexique.org/

Noonan, K. A., Jefferies, E., Garrard, P., Eshan, S., & Lambon Ralph, M. A. (2013). Demonstrating the qualitative differences between semantic aphasia and semantic dementia: A novel exploration of nonverbal semantic processing. *Behavioural Neurology*, *26*(1-2), 7-20. https://doi.org/10.3233/BEN-2012-110200

Nyberg, L., Maitland, S. B., Rönnlund, M., Bäckman, L., Dixon, R. A., Wahlin, A., & Nilsson, L.-G. (2003). Selective adult age differences in an age-invariant multifactor model of declarative memory. *Psychology*

and Aging, *18*(1), 149-160. https://doi.org/10.1037/0882-7974.18.1.149

Park, D. C., Lautenschlager, G., Hedden, T., Davidson, N. S., Smith, A. D., & Smith, P. K. (2002). Models of visuospatial and verbal memory across the adult life span. *Psychology and aging*, *17*(2), 299-320.

Pollet, M., Moroni, C., Jacquemont, C., Debachy, B., Kurth, S., Pasquier, F., … & Delbeuck, X. (2019). Le *Repeat and Point Test* : un outil de *screening* discriminant des profils de troubles langagiers dans le cadre des affections neurodégénératives. *Revue de neuropsychologie*, *11*(2), 151-158.doi:10.1684/nrp.2019.0491

Puel, M., Bezy-Vié, C., Busigny, T., Cazaux, P., Arrabie, L., Basaglia-Pappas, S., Barbeau, E. J., Pariente, J., & Thomas-Anterion, C. (2016). Gretop Visages et Gretop Noms: mémoire des personnes célèbres, un outil d'aide au diagnostic précoce dans les pathologies neurodégénératives. *Revue de neuropsychologie*, *8*(3), 201-214.

Saygin, A. P., Dick, F., Wilson, S. M., Dronkers, N. F., & Bates, E. (2003). Neural resources for processing language and environmental sounds: Evidence from aphasia. *Brain: A Journal of Neurology*, *126*(Pt 4), 928-945. https://doi.org/10.1093/brain/awg082

Shallice T. Specialisation within the semantic system. *Cognitive neuropsychology*, *5*(1), 133-142, 1988.

Simoes Loureiro, I., & Lefebvre, L. (2015). Le QCS : Questionnaire de connaissances sémantiques pour déterminer le stade de détérioration sémantique chez les patients atteints de la maladie d'Alzheimer. *Gériatrie et psychologie neuropsychiatrie du vieillissement*, *13*(2), 225-233.Doi :10.1684/pnv.2015.0535. PMID: 26103114.

Snowden, J. S., Thompson, J. C., & Neary, D. (2004). Knowledge of famous faces and names in semantic dementia. *Brain: a journal of neurology*, *127*(Pt 4), 860-872. https://doi.org/10.1093/brain/awh099

Strain, E., Patterson, K., & Seidenberg, M. S. (1995). Semantic effects in single-word naming. *Journal of experimental psychology. Learning, memory, and cognition*, *21*(5), 1140-1154. https://doi.org/10.1037//0278-7393.21.5.1140

Tee, B. L., & Gorno-Tempini, M. L. (2019). Primary progressive aphasia: A model for neurodegenerative disease. *Current opinion in neurology*, *32*(2), 255-265. https://doi.org/10.1097/WCO.0000000000000673

Teichmann, M. (2019). Les aphasies primaires progressives. *Pratique Neurologique-FMC*, *10*(2), 96-100.https://doi.org/10.1016/j.praneu.2019.02.002

Thompson, H. E., Almaghyuli, A., Noonan, K. A., Barak, O., Lambon Ralph, M. A., & Jefferies, E. (2018). The contribution of executive control to semantic cognition: Convergent evidence from semantic aphasia and executive dysfunction. *Journal of Neuropsychology*, *12*(2), 312-340. https://doi.org/10.1111/jnp.12142

Toepper M. (2017). Dissociating Normal Aging from Alzheimer's Disease: A View from Cognitive Neuroscience. *Journal of Alzheimer's disease*, *57*(2), 331-352. https://doi.org/10.3233/JAD-161099

Tran, T. M., Dasse, P., Letellier, L., Lubjinkowic, C., Thery, J., & Mackowiak, M.-A. (2012). Les troubles du langage inauguraux et démence : Étude des troubles lexicaux auprès de 28 patients au stade débutant de la maladie d'Alzheimer. *SHS Web of Conferences*, *1*, 1659-1672. https://doi.org/10.1051/shsconf/20120100211

Tran, T. M. (2018). Traitement orthophonique des troubles lexico-sémantiques. *Rééducation orthophonique*, *275*, 117-132.

Tran, T. M., & Godefroy, O. (2015). *Batterie d'Évaluation des Troubles Lexicaux*, Isbergues, Ortho Edition.

Tran, T. M., & Godefroy, O. (2011). La Batterie d'Évaluation des Troubles Lexicaux: effet des variables démographiques et

linguistiques, reproductibilité et seuils préliminaires. *Revue de neuropsychologie*, *3*(1), 52-69.

Tulving, E. (1972). 12. Episodic and Semantic Memory. In E. Tulving, W. Donaldson, *Organization of memory*, Cambridge (Mass.) : Academic Press, 381-403.

Turcotte, V., Gagnon, M. E., Joubert, S., Rouleau, I., Gagnon, J. F., Escudier, F., Koski, L., Potvin, O., Macoir, J., & Hudon, C. (2018). Normative data for the Clock Drawing Test for French-Quebec mid- and older aged healthy adults. *The Clinical neuropsychologist*, *32*, 91-101. https://doi.org/10.1080/13854046.2018.1473495

Verma, M., & Howard, R. J. (2012). Semantic memory and language dysfunction in early Alzheimer's disease: A review. *International Journal of Geriatric Psychiatry*, *27*(12), 1209-1217. https://doi.org/10.1002/gps.3766

Warrington, E. K., & Shallice, T. (1984). Category specific semantic impairments. *Brain: a journal of neurology*, *107*, 829-854. https://doi.org/10.1093/brain/107.3.829