Analysis of Naming Errors in Healthy Aging, Mild Cognitive Impairment, and Alzheimer's Disease

Analyse des erreurs de dénomination dans le vieillissement normal, le trouble cognitif léger et la maladie d'Alzheimer

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Mélanie Gallant
Monica Lavoie
Carol Hudon
Laura Monetta

Mélanie Gallant, Monica Lavoie, Carol Hudon, and Laura Monetta

Université Laval, Québec, QC, CANADA

CERVO, Brain Research Centre, Québec, QC, CANADA

Abstract

The aim of this study was to document the functional origin of anomia in mild cognitive impairment in comparison to Alzheimer's disease and healthy cognitive aging. An oral naming task of 260 pictures was administered to 20 individuals with mild cognitive impairment, 5 with mild Alzheimer's disease, and 15 healthy controls. The mean total number of errors and types of naming errors were compared across the groups. The effect of psycholinguistic parameters and the efficacy of semantic and phonological cueing were also analyzed. Results showed a significant difference among the three groups' total number of naming errors (Alzheimer's disease > mild cognitive impairment > healthy controls). Similar types of naming errors were found among the groups and mainly consisted of coordinate semantic paraphasias. Further, less familiar words were associated with greater error probability in all groups. Finally, based on error types, psycholinguistic parameters, and efficacy of cueing, the main origin of anomia was determined for each participant and different patterns were observed among the three groups. In healthy controls, the origin of anomia was lexical. In mild cognitive impairment, the origin of anomia was lexical for 60% and semantic for 40% of participants. In Alzheimer's disease, a degradation of fine and distinctive semantic features seems to be the main cause of anomia. Although the present data are limited due to small sample size, they will be useful in the development of appropriate interventions aiming to reduce anomia in the elderly.

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Abrégé

L'objectif de la présente étude était de documenter l'origine fonctionnelle de l'anomie chez des individus ayant un trouble cognitif léger, lorsque comparés à des individus atteints de la maladie d'Alzheimer et des individus ayant un vieillissement cognitif normal. Pour ce faire, une tâche de dénomination orale, composée de 260 stimuli visuels, a été administrée à 20 individus ayant un trouble cognitif léger, 5 individus atteints d'une forme légère de la maladie d'Alzheimer et 15 individus ayant un vieillissement cognitif normal. Le nombre total d'erreurs de dénomination, ainsi que le type d'erreurs, ont été comparés. L'influence des propriétés psycholinguistiques des mots, ainsi que l'efficacité de l'indiçage phonologique et sémantique, sur la probabilité de commettre une erreur ont également été analysées. Les résultats ont révélé des différences significatives entre les trois groupes quant au nombre total d'erreurs de dénomination (maladie d'Alzheimer > trouble cognitif léger > vieillissement cognitif normal). Néanmoins, le type d'erreurs effectuées par les individus des trois groupes était similaire; il s'agissait principalement d'erreurs de type paraphasies sémantiques coordonnées. Ajoutons également que les mots moins familiers étaient associés à un plus grand risque d'erreurs dans les trois groupes. Enfin, en s'appuyant sur le type d'erreurs effectuées par les individus de chaque groupe, l'influence des paramètres psycholinguistiques et l'efficacité de l'indiçage, l'origine fonctionnelle de l'anomie a été déterminée pour chaque participant. Différents patrons ont été observés pour chacun des trois groupes. Chez les individus ayant un vieillissement cognitif normal, l'origine de l'anomie était principalement lexicale. Chez les individus ayant un trouble cognitif léger, l'origine de l'anomie était lexicale dans 60% des cas, alors qu'elle était sémantique dans l'autre 40% des cas. Chez les individus atteints de la maladie d'Alzheimer, la dégradation des caractéristiques sémantiques fines et distinctives semblait être la principale cause de l'anomie. Malgré les limitations dues à la taille de l'échantillon, les données recueillies dans le cadre de la présente étude seront utiles au développement d'interventions visant à réduire l'anomie des personnes âgées.

Alzheimer's disease (AD) is a neurodegenerative disorder leading to a progressive cognitive and functional decline. AD is typically preceded by a prodromal phase, the most frequent being mild cognitive impairment (MCI; Albert et al., 2011). Various cognitive symptoms can be found in MCI, but when it is associated with an underlying AD, a deficit in episodic memory is the core feature (Belleville, Sylvain-Roy, de Boysson, & Ménard, 2008; Hudon, Villeneuve, & Belleville, 2011). Impairments in other cognitive functions can also be observed, such as semantic memory (Belleville et al., 2008; Callahan et al., 2015; Joubert et al., 2008; Salmon, 2012), executive functions (Johns et al., 2012), visuospatial functions (Mitolo et al., 2013), and language (for reviews, see Taler & Phillips, 2008, and Tsantali, Economidis, & Tsolaki, 2013).

Compared to other cognitive functions, fewer studies have investigated language impairment in MCI. Yet, anomia (word-finding difficulties) is one of the most frequent complaints of people with MCI (Taler & Phillips, 2008). Anomia is usually assessed using a naming task where the participant has to produce the specific word corresponding to an object or image. According to the cognitive model proposed by Caramazza and Hillis (1990), oral naming of pictures involves the serial activation of several components including (a) pictographic analysis, (b) structural representations lexicon, (c) semantic system, (d) phonological output lexicon, (e) phonological buffer, and (f) articulatory system. The number of naming errors determines the presence of anomia, while the types of errors are essential to determine the functional origin of the impairment (Grima & Franklin, 2017).

In an oral picture naming task (e.g., "apple"), errors can be classified into several types (Bogliotti, 2012): (a) visual error, a perceptual error without a semantic link to the target word (i.e., "ball"); (b) superordinate categorical semantic paraphasia, naming the general category of the target word (i.e., "fruit"); (c) coordinate categorical semantic paraphasia, naming an object in the same category of the target word (i.e., "pear"); (d) associative semantic paraphasia, the production of a word with a semantic association to the target word, without regard to the grammatical class (i.e., "juice"); (e) visuosemantic error, an error that could be classified as perceptual but also as semantic (i.e., "peach"); (f) phonological paraphasia, a segmental error within the phonological form of the word (i.e., "papple"); (g) vague circumlocution, a summary description of the word that does not include any distinctive features of the object (i.e., "fruit with peel") and that is used as a compensatory strategy for anomia; (h) precise circumlocution, which is a more detailed description of the object (i.e., "fruit with peel, it could be red or green and it is used to make juice or pie") and that is also used as a compensatory strategy for anomia; (i) sequences of phonemic approximation, successive attempts to produce the target word (i.e., "an a, an ap, an apple"); and (j) neologism, the production of a word that does not belong to the lexicon of a specific language (i.e., "kivos"). It is also possible to have other types of manifestations like perseveration, the repetition of the same word in response to different target words (i.e., "bread" for several consecutive items); stereotypy, the repetition of a syllable, a word, or a fixed expression (i.e., "p, p, p" or fixed expression in the naming attempts); tip-of-the-tongue, the feeling that retrieval is imminent (i.e., "I know what it is, but I can't find the exact word"); and non-responses, that is when no answer is attempted (i.e., "I don't know").

According to the Caramazza and Hillis (1990) model, an impairment of pictographic analysis or structural representations lexicon could lead to the production of visual errors. An impairment at the semantic level (difficulty to access or retrieve the semantic feature of the target) could result in the production of non-responses, vague circumlocutions, or semantic paraphasias. An impairment at the lexical level (difficulty in the access or within the phonological output lexicon) could result in tip-of-the-tongue, production of precise circumlocutions, and phonological or semantic paraphasias (Chomel-Guillaume, Leloup, Bernard, Riva, & François-Guinaud, 2010). Finally, an impairment of the phonological buffer usually causes successive attempts to produce the target word through sequences of phonemic approximations.

In addition to the analysis of the error types, the analysis of the efficacy of semantic and phonological cues in a naming task increases the understanding of the functional origin of anomia (Nickels, 2001; Whitworth, Webster, & Howard, 2013). Indeed, when naming is facilitated by the production of the first sound of the target word (phonological cue), this leads to a lexical origin of anomia. In contrast, when naming is facilitated by the production of semantic features associated with the target word (semantic cue), the origin of anomia is more likely semantic. Psycholinguistic parameters, such as frequency, subjective frequency, and semantic category, can also have a notable influence on naming performance (Whitworth et al., 2013). Indeed, retrieval of the semantic features within semantic memory is influenced by subjective frequency (the frequency modulated by individuals' experience) and category (e.g., biological vs. manufactured), while retrieval of the phonological representations within the phonological output lexicon is influenced mainly by frequency (occurrence of a word, compared to other words in a specific language). Even if imageability (the ease with which

a word evokes a visual or auditory picture) also influences the production of words, its impact is minimized in oral naming tasks because all visual stimuli typically imply a high level of imageability. Finally, word length has an impact in oral naming performance because the more sounds a word contains, the more difficult it is to maintain it in short-term memory (for more information see Chomel-Guillaume et al., 2010, and Whitworth et al., 2013).

According to the current body of research exploring anomia in MCI, biological items are more impaired than manufactured ones (Callahan et al., 2015; Duong, Whitehead, Hanratty, & Chertkow, 2006; Taler, Voronchikhina, Gorfine, & Lukasik, 2016), even if some authors found no impact of semantic category on performance (Laws, Adlington, Gale, Moreno-Martínez, & Sartori, 2007; Lockyer, Sheppard, & Taler, 2015). Quantitatively, anomia is less prominent in MCI than in AD (Balthazar, Cendes, & Damasceno, 2008; Lin et al., 2014). Results are less consistent when individuals with MCI are compared to healthy controls (HC). Indeed, some authors found that anomia was more prominent in MCI (Adlam, Bozeat, Arnold, Watson, & Hodges, 2006; Balthazar et al., 2008; Balthazar, Yasuda, Cendes, & Damasceno, 2010; Dudas, Clague, Thompson, Graham, & Hodges, 2005), while no difference between the two groups was found in other studies (Beinhoff, Hilbert, Bittner, Grön, & Riepe, 2005; Willers, Feldman, & Allegri, 2008).

Most studies analyzing the types of naming errors were conducted with AD participants (i.e., Barbarotto, Capitani, Jori, Laiacona, & Molinari, 1998; Cuetos, Gonzalez-Nosti, & Martínez, 2005; Gonnerman, Aronoff, Almor, Kempler, & Andersen, 2004; Lin et al., 2014; Silagi, Bertolucci, & Ortiz, 2015). Lin et al. (2014) concluded that a progressive degradation of the semantic system was responsible for anomia in AD, given the predominance of non-responses and semantic errors. However, they did not take into account the psycholinguistic parameters. There is no agreement on the origin of anomia in MCI. Some studies suggest a semantic origin (Adlam et al., 2006; Joubert et al., 2010; Willers et al., 2008), while others suggest a lexical-semantic one (Balthazar et al., 2008; Duong et al., 2006; Guidi, Paciaroni, Paolini, Scarpino, & Burn, 2015; Taler & Phillips, 2008), namely an impairment in both the semantic system and the phonological output lexicon. Until now, only two studies have documented the patterns of naming errors in MCI. Balthazar et al. (2008) compared the naming performances of individuals with MCI, AD, and HC. They found that the three groups were statistically different regarding number of correct answers, but had a similar pattern of errors: (a) coordinate semantic errors, (b) superordinate semantic errors, (c) circumlocutions, (d) visual errors, and (e) non-responses. The authors concluded that the observed errors came from a combination of partial degradation of the semantic system (predominance of semantic errors) and impairment in the phonological output lexicon and its access (effectiveness of phonological cueing). Willers et al. (2008) also compared the performance of MCI, AD, and HC participants. They found that the performance of participants with MCI was similar to those with HC regarding the number of correct answers, but better than participants with AD. Results also showed a similar pattern of error types in MCI and AD: (a) semantic errors, (b) non-responses, (c) visual errors, (d) other errors, and (e) phonological paraphasias. Based on these results, specifically the predominance of semantic errors and non-responses, the authors concluded that the naming errors were caused by an impairment of the semantic system.

Studies published to date have several limitations. First, there is a lack of precision in the classification of naming errors used by Balthazar et al. (2008) and Willers et al. (2008). Indeed, their classification did not take into account the difference between precise circumlocutions (precise expressions, including specific semantic features and generally associated with a lexical deficit) and vague circumlocutions (approximate or imprecise expression without specific semantic features, and generally associated with a semantic deficit; see Chomel-Guillaume et al., 2010; Whitworth et al., 2013). Moreover, psycholinguistic parameters (frequency, semantic category, subjective frequency) were not taken into account, despite the fact that they have an impact on oral naming (Whitworth et al., 2013) as described above. Finally, the authors used no objective measures to assess the integrity of visual recognition (e.g., object decision task), which limits the interpretation of the naming errors. Indeed, both studies used a picture-based oral naming task without determining that the participant had no visual agnosia. Also, the studies did not assess the integrity of the semantic system; however, an appropriate assessment could support the conclusion regarding the origin of anomia.

The aim of this study was to document the functional origin of anomia in participants with MCI in comparison to those with AD or HC. Specific objectives were to (a) quantitatively analyze the naming errors in the three groups to compare their performance to confirm the presence and severity of anomia and (b) qualitatively analyze the naming errors, taking into account the effects of psycholinguistic parameters and the effectiveness of semantic and phonological cueing. It was expected that the three groups would show different degrees of anomia following a

continuum of severity (HC<MCI<AD). It was also expected that the analysis of naming errors combined with the effect of psycholinguistic parameters and cueing would highlight a lexical-semantic origin to explain the naming impairment in participants with MCI and AD (Balthazar et al., 2008; Duong et al., 2006; Guidi et al., 2015; Taler & Phillips, 2008).

Method

Participants

Initially, 60 participants were recruited: 12 with mild AD, 29 with MCI, and 19 HC. The study's final sample consisted of 40 participants aged 55 years and older: five with mild AD, 20 with amnestic MCI (14 single domain and six multiple domains), and 15 HC. Twenty participants were excluded from the initial sample because they had probable visuoperceptual difficulties according to the Object Decision subtest of the Birmingham Object Recognition Battery (Riddoch & Humphreys, 1993). Participants in the HC group were recruited from a database of cognitively and physically healthy older subjects and none had cognitive impairments or mental health disorders. Participants in the AD and MCI groups were referred by collaborating physicians or recruited through pamphlets distributed in medical clinics in Québec City (Canada). Participants with AD met the core clinical diagnostic criteria proposed by McKhann et al. (2011) and participants with MCI met the clinical diagnostic criteria of Albert et al. (2011). All participants in the MCI group had mild episodic memory impairment (with or without impairment in other cognitive domains).

For all participants, exclusion criteria were (a) neurodegenerative disorder (e.g., Parkinson's disease, multiple sclerosis), (b) history of moderate or severe traumatic brain injury or stroke, (c) interventions that may affect cognitive functioning (e.g., general anesthesia in the last 6 months, etc.), (d) delirium in the last 6 months or clinically significant psychiatric disorder according to the criteria of the DSM-IV-TR, (e) untreated or unstable medical or metabolic condition, (f) history of encephalitis or bacterial meningitis, (g) alcoholism or substance abuse in the last 12 months, (h) uncorrected visual or auditory problems, (i) incapacity to give consent to the study procedures, and (j) visual agnosia or probable visuoperceptual difficulties.

Material and Procedures

Two 2-hour sessions took place either at the research centre or at home, depending on the participant's choice. When sessions took place at the research centre, participants were offered a financial compensation of $20 per session for their travel expenses. The study procedures were approved by the Ethics Research Board of the Institut universitaire en santé mentale de Québec (approval #220).

Clinical and neuropsychological assessment. During the first assessment session, a clinical and neuropsychological battery was administered to confirm the diagnosis of AD or MCI in the clinical groups, or the absence of cognitive impairment in the HC group. The battery also aimed at verifying exclusion criteria. General cognitive functioning was assessed with the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005; normative data by Larouche et al., 2015), depressive symptoms with the French version of the Geriatric Depression Scale (Bourque, Blanchard, & Vézina, 1990; Yesavage, 1988), and memory complaint with the Cognitive Complaints Questionnaire (*Questionnaire de plainte cognitive*; Thomas-Antérion, Ribas, Honoré-Masson, Million, & Laurent, 2004). Verbal episodic memory was evaluated with the 16-item Free/Cued Recall task (Van der Linden et al., 2004; normative data by Dion et al., 2015), and visual episodic memory with the immediate recall (3 minutes) of the Rey Complex Figure (Rey, 1960; normative data by Tremblay et al., 2015). The Rey Complex Figure was also used to assess visuoconstructive functions. Visual agnosia was evaluated using the Object Decision task (difficult test) of the Birmingham Object Recognition Battery (Riddoch & Humphreys, 1993). Semantic memory was assessed with the Pyramids and Palm Trees Test (Howard & Patterson, 1992; normative data by Callahan et al., 2010) and executive functions were assessed with the Stroop test of the D-KEFS battery (Delis, Kaplan, & Kramer, 2001). Finally, the battery included a task of phonemic (i.e., letters T, N, P) and semantic (i.e., animals) verbal fluency. For each group, results of the clinical and neuropsychological evaluations are presented in the Results.

Anomia assessment. During the second session, anomia was assessed for each participant using a computerized naming task (MS PowerPoint©) comprising the 260 visual stimuli of Snodgrass and Vanderwart (1980). The colour version of the pictures was used (Rossion & Pourtois, 2004). Frequency (n = 228 words), category (n = 260), and subjective frequency (n = 239) of the words were known for almost all stimuli (n = 260) of Snodgrass and Vanderwart. Those psycholinguistic parameters were found in the OMNILEX Canadian database from the University of Ottawa (Desrochers, 2006). Values for each parameter were the following: frequency (low, moderate, high), subjective frequency (low, moderate, high), and semantic category (biological, manufactured). Imageability and word length were not manipulated in this study because, as it was said previously, all visual stimuli typically imply a high

level of imageability and word length's effect is related to a post-lexical treatment, at the phonological buffer level, a component that is not affected in AD.

For the naming task, participants were asked to name the objects that appeared in the centre of the computer screen. Responses were audio recorded. Two practice items, not included in the Snodgrass and Vanderwart (1980) images, were presented first to the participants. For each stimulus, participants had a maximum of 15 seconds to answer. If the answer was correct, the next stimulus was presented. If participants were unable to name an object after 15 seconds or gave a wrong answer, a semantic cue was given. For manufactured items (e.g., glass), the semantic cue always referred to the category and the use of the object (i.e., a kitchen tool used to drink), while for biological items (e.g., apple) the cue referred to the category and a perceptual characteristic of the object (i.e., a fruit that is generally red). Following the cue, participants had a maximum of 10 seconds to name the object. If the answer was correct, the next image was presented. However, if the answer was still wrong a phonological cue (first sound of the word) was given and participants had a maximum of 10 seconds to answer. If participants were still unable to give the correct answer, no feedback was provided and the next picture was presented.

Data Analysis

Error analysis. Incorrect spontaneous answers (i.e., before semantic or phonological cueing) were classified into 15 types of errors (Bogliotti, 2012). To ensure the error analysis was reliable, two independent raters analyzed types of errors made by the participants. To compare the sociodemographic, clinical, and neuropsychological characteristics of the three groups, analysis of variance (ANOVA) was used for continuous variables and Pearson's chi-square test was used for binary variables. An ANOVA was also used to compare the efficacy of semantic and phonological cueing between groups. An exact logistic regression model was used to evaluate the difference among the three groups' naming errors in spontaneous answers. An exact approach was used to take into account the small sample size of the AD group (Mehta & Patel, 1995). A mixed-effect Poisson model was then applied to compare the patterns of errors among groups. This model uses the logarithm on the number of errors as the link function, considers the participant as a random effect, and uses an offset corresponding to the logarithm of the total number of errors made by the participants. The sources of variance composing the fixed part of this model are the groups, the types of errors, and the interaction between these two main effects. The first source analyzes the between-subjects variability while the others analyze the within-subjects variability. Finally, naming errors were committed on 93 of the 260 assessed words. The probability to commit an error among those 93 words was compared among the groups and among the three psycholinguistic parameters (i.e., frequency, subjective frequency, and category) using a logistic regression model with the participant treated as a random effect. The addition of this random effect made it possible to take into account the dependence between a participant's observations. For all analyses, Tukey-Kramer multiple comparisons were performed on a significant result of a variation source. Analyses were performed using the SAS software for Windows (version 9.4, SAS Inc., NC) with a significance level of $p \leq .05$.

Individual's profile. Two of the authors (ML and LM) analyzed clinically the data for all participants to determine the main functional origin of anomia (i.e., lexical or semantic) based on error patterns and efficacy of semantic and phonological cueing. Specifically, for each participant, the number of each type of error was calculated as well as the percentage of efficacy of semantic and phonological cueing allowing the classification into lexical (associated with a predominance of coordinate semantic paraphasias and precise circumlocutions as well as good efficacy of phonological cueing) and semantic (associated with a predominance of non-responses, coordinate and superordinate semantic paraphasias, and vague circumlocutions along with a poor efficacy of phonological cueing) profiles. Following clinical analyses, participants ($n = 3$) with profiles not clearly related to a semantic or lexical origin were re-analyzed conjointly by the two authors to reach a consensus.

Results

The three groups did not differ significantly in age and education. There were significantly more men in the MCI group, but since results remained unchanged when sex was added as a covariate, results of the present study were not corrected for this variable. **Table 1** shows that none of the HC participants had a self-reported cognitive complaint, but more than half of the MCI participants and two-thirds of the AD patients subjectively complained about their cognitive functioning. Compared to the HC group, participants with MCI showed cognitive impairments in several domains, namely general cognitive functioning, episodic memory, executive functions, and semantic verbal fluency. In addition, there were more depressive symptoms among MCI participants than for those in the HC group. Participants with AD also had depressive symptoms as well as cognitive impairments in almost every domain except semantic memory, visual perception, and visuoconstruction. Cognitive impairments were generally more severe in the AD than in the MCI group.

Table 1

Sociodemographic and Clinical Data of the Participants

	HC (*n* = 15)	MCI (*n* = 20)	AD (*n* = 5)		
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*F* or χ^2	*p*
Sociodemographic characteristics					
Age (years)	70.7 (7.8)	71.8 (7.8)	77.2 (8.9)	1.3	.285
Sex (male/female)	6/9	14/6	3/2	18.4	< .001
Education (years)	14.9 (3.5)	14.5 (2.5)	15.0 (3.6)	0.1	.973
General cognitive functioning					
MoCA (/30)	26.8 (2.4)[c]	24.4 (2.5)	20.3 (2.3)[a]	11.6	**.001**
Cognitive complaint					
QPC (% of participants with a complaint)	0[bc]	53.8	66.7	8.1	**.018**
Depressive symptoms					
GDS (/30)	1.4 (2.2)[bc]	5.0 (3.3)	6.7 (5.0)	6.6	**.004**
Episodic memory					
16-item mean free recall (/16)	15.1 (1.3)	12.3 (2.4)	5.7 (2.5)	27.2	**< .001**[d]
16-item mean total recall (free + cue) (/16)	15.1 (1.1)	12.8 (2.5)	6.3 (3.1)	21.9	**< .001**[d]
16-item delayed free recall (/16)	15.7 (0.5)	13.5 (2.3)	6.7 (1.2)	29.0	**< .001**[d]
16-item delayed total recall (free + cued) (/16)	15.8 (0.4)	13.2 (2.3)	6.3 (3.1)	31.6	**< .001**[d]
Recall of the Rey Complex Figure (3 min) (/36)	19.6 (6.0)	13.3 (4.5)	0.3 (0.6)	19.9	**< .001**[d]
Semantic memory					
PPTT (/52)	50.2 (1.3)	49.5 (1.6)	49.8 (1.9)	0.9	.415
Perception/visual gnosis and visuoconstructive abilities					
Size-match task of the BORB (/30)	27.6 (1.3)	26.3 (1.9)	25.7 (2.3)	3.0	.063
Object decision (/32)	27.0 (1.8)	27.1 (2.3)	26.8 (1.7)	0.0	.992
Copy of the Rey Complex Figure (/36)	29.9 (4.4)	30.8 (4.3)	28.5 (4.0)	0.4	.649
Executive functions					
Stroop D-KEFS, Inhibition (seconds)	60.3 (10.6)	80.8 (15.2)	102.3 (6.0)	17.3	**< .001**[d]
Stroop D-KEFS, Inhibition/Shifting (seconds)	68.9 (18.0)[c]	83.4 (30.0)[c]	180.0 (0.0)[ab]	17.1	**< .001**
Stroop D-KEFS, Inhibition (errors)	1.2 (1.2)[c]	3.2 (1.8)	6.7 (9.0)[a]	5.4	**.010**
Stroop D-KEFS, Inhibition/Shifting (errors)	1.9 (1.6)	4.4 (5.4)	4.5 (2.1)	1.6	.217
Language					
Verbal fluency, letters T-P-N	38.6 (9.4)[c]	32.6 (7.1)	24.7 (6.8)[a]	4.6	**.018**
Semantic fluency, animals	18.6 (4.2)[b]	14.3 (4.8)[a]	14.0 (7.5)	3.6	.037

Note. Text in bold indicates a statistically significant difference. AD = Alzheimer's disease; BORB = Birmingham Object Recognition Battery; D-KEFS = Delis-Kaplan Executive Function System; GDS = Geriatric Depression Scale; HC = Healthy cognitive aging; MCI = Mild cognitive impairment; MoCA = Montreal Cognitive Assessment; PPTT = Pyramids and Palm Trees Test; QPC = Questionnaire de plainte cognitive; RL/RI = Free recall/cued recall 16 items.
[a]$p < .05$ compared to HC. [b]$p < .05$ compared to MCI. [c]$p < .05$ compared to AD. [d]The three groups are different $p < .05$.

Number of Errors: Differences Among the Groups

A significant difference was found among the groups for mean number of naming errors in spontaneous answers, $\chi^2(2) = 38.13$, $p < .001$. Likelihood ratios showed a significant difference among the three groups, with the AD group committing the highest mean number of errors (21.8 ± 2), followed by the MCI group (14.5 ± 0.8) and the HC (10.2 ± 0.8) group.

Errors Patterns: Differences Among the Groups

Analyses revealed no interaction effect between Group and Types of Errors, $F(22, 407) = 0.79$, $p = .734$. As a main effect, the effect of Group remained non-significant, $F(2, 37) = 0.26$, $p = .771$, while the effect of Types of Errors was significant, $F(11, 407) = 40.31$, $p < .001$. The absence of an interaction between both factors reveals a similar pattern of errors among the three groups. Therefore, the following results (mean number of errors) include all study participants. Multiple comparisons for the Types of Errors effect indicated that participants committed mostly coordinate semantic errors, followed by errors of the following types: visuosemantic (likely to be semantic since no visual agnosia was found on the Birmingham Object Recognition Battery), precise circumlocutions, non-responses, superordinate semantic, vague circumlocutions, associative categorical semantic, visual, errors classified as "others," phonological paraphasia, perseverations, and sequences of phonemic approximations (see **Table 2**). No tip-of-tongue, neologisms, or stereotypy were observed.

Efficacy of Semantic and Phonological Cueing

Analyses revealed no significant difference among the groups' percentages of correct responses following semantic, $F(2, 37) = 2.21$, $p = .124$, or phonological, $F(2, 36) = 0.11$, $p = .893$, cues. As for intragroup analysis, semantic and phonological cueing improved naming: 18.8% and 40.5% for the AD group, 16.6% and 42.0% for the MCI group, and 28.2% and 45.6% for the HC group, respectively. Given the sequential order in which the semantic and phonological cues were given, it was impossible to determine whether this intragroup difference was significant.

Influence of Psycholinguistic Parameters

The analyses revealed no interaction between Group and the three psycholinguistic parameters: Category, $F(2, 3658) = 0.32$, $p = .728$, subjective frequency, $F(4, 3658) = 1.21$, $p = .304$, and frequency, $F(4, 3658) = 1.25$, $p = .289$. As a main effect, Group remained non-significant, $F(2, 37) = 0.84$, $p = .441$, while only subjective frequency, $F(2, 3658) = 13.70$, $p < .001$, significantly influenced naming performance. Multiple comparisons showed that participants committed more errors when they had to name less familiar words (see **Table 3**). However, category, $F(1, 3658) = 0.93$, $p = .335$, and frequency, $F(2, 3658) = 0.29$, $p = .749$, did not significantly influence the probability of a naming error.

Individual Profiles

While anomia in the HC and AD groups was clearly related to lexical access difficulty (80%) and semantic deterioration (80%), respectively, two profiles were found for the MCI group. The origin of anomia was lexical for 60% of the MCI participants and semantic for 40%. When compared, the two subgroups did not differ in terms of age ($p = .235$), education ($p = .092$), or MoCA score ($p = .078$).

Discussion

The aim of this study was to document the functional origin of anomia in participants with MCI, in comparison to individuals with AD or HC, by performing a quantitative and qualitative analysis of naming errors. The efficacy of semantic and phonological cueing and the influence of psycholinguistic parameters were taken into account. Despite the relatively small number of naming errors made by all participants in the study, results showed a significant difference among the groups. Namely, participants with AD made the most errors, followed by MCI participants, and finally HC. However, the pattern of naming errors was similar in the three groups. Coordinate semantic errors, precise circumlocutions, non-responses, superordinate semantic errors, and vague circumlocutions were the most frequent types of incorrect responses. Regarding psycholinguistic parameters, results from our study showed that subjective frequency had a significant influence on the probability to commit an error in the three groups.

Quantitative and Qualitative Analysis of Naming Errors

The present study showed that individuals with AD committed more naming errors than individuals with MCI or HC, which is in line with results obtained in previous studies (Balthazar et al., 2008; Lin et al., 2014; Willers et al., 2008). Regarding participants with MCI, the present results are consistent with studies that showed the presence of anomia in individuals with MCI (Adlam et al., 2006; Balthazar et al., 2008; Balthazar et al., 2010; Dudas et al., 2005). However, one should keep in mind that other studies found no significant difference in the naming capacity of MCI and HC participants (Beinhoff et al., 2005; Willers et al., 2008). Despite a significant difference among the groups, AD and MCI participants committed only a few naming errors, thus suggesting the presence of naming difficulties rather than a naming impairment.

Table 2

Total Number of Each Type of Naming Error Committed by all Participants

	All participants (n = 40)	
Type of Naming Error	Total (*SD*)	Tukey-Kramer[a]
Coordinate semantic paraphasias	42.3 (2.9)	a
Visuosemantic paraphasias	11.9 (1.5)	b
Precise circumlocutions	10.9 (1.4)	b
Non-responses	8.9 (1.3)	cb
Superordinate semantic paraphasias	8.5 (1.2)	cb
Vague circumlocutions	6.3 (1.1)	bcd
Associative semantic paraphasias	4.7 (0.9)	cde
Visual	3.4 (0.8)	de
Others	2.2 (0.6)	de
Phonological paraphasias	0.5 (0.3)	e
Perseverations	0.2 (0.2)	e
Sequences of phonemic approximations	0.2 (0.2)	e

Note. [a]Comparisons sharing a same letter are not significantly different.

Table 3

Naming Errors Committed by all Participants According to Psycholinguistic Parameters

	All participants (n = 40)		
	M (*SD*)	*F*	*p*
Subjective frequency		13.3	< .001
High	9.7 (2.5)		
Moderate	14.5 (3.7)		
Low	28.8 (7.2)		
Frequency		1.2	.315
High	9.5 (6.5)		
Moderate	23.1 (4.6)		
Low	19.0 (2.0)		
Category		1.0	.327
Biological	17.2 (4.2)		
Manufactured	15.5 (3.8)		

The similar pattern of naming errors among the three groups in the present study is also consistent with results from previous studies (i.e., Balthazar et al., 2008; Lin et al., 2014; Willers et al., 2008). More specifically, Balthazar et al. (2008) showed a similar pattern of naming errors among HC, MCI, and AD participants. Lin et al. (2014) reported a similar distribution of the types of errors in individuals with AD and controls, but participants with MCI were not included in the study. Finally, Willers et al. (2008) found a similar pattern of errors in participants with AD and MCI, but not in controls who committed significantly less semantic errors. Taking into account only the type of naming errors, our results suggest an implication of the same components in naming in individuals with AD, MCI, and HC, with a gradual degradation of these components following the severity of the cognitive impairment.

Regarding the types of errors found in the present study, there are many similarities with data from previous work. Two main findings can be drawn: (a) coordinate semantic errors are very common, while (b) phonological paraphasias are very rarely produced by HC, MCI, or AD participants. The strong presence of coordinate semantic paraphasias could suggest an impairment in the access or retrieval of the semantic features among the semantic memory, in line with the literature targeting a semantic origin for anomia in MCI (Adlam et al., 2006; Joubert et al., 2010; Willers et al., 2008), but also could suggest a lexical access difficulty (Whitwort et al., 2013), targeting a more lexical origin. Since precise circumlocutions, usually associated with a lexical origin, were the second most frequent type of errors, this must be interpreted carefully. Moreover, results from the present study allowed us to be more specific about the types of errors reported in the literature. Indeed, in this study, compensation strategies for anomia like circumlocutions were differentiated into precise circumlocutions, habitually associated with a lexical impairment (i.e., difficulty to access the precise word but spared semantic knowledge) and vague circumlocutions, rather associated with a semantic deficit (i.e., difficulty to access the word and impaired semantic knowledge), a distinction that was not made in previous work. In this study, precise circumlocutions were more frequent than vague circumlocutions.

Psycholinguistic Parameters and Cueing

For all participants, errors were mostly committed for less familiar words, without significant effects of category and frequency. The absence of category and frequency effects could be explained by a lack of statistical power caused by high variability in the parameters associated with the 93 words that yielded an error at least once in the naming task. A bigger sample would have allowed us to observe higher numbers of naming errors, thus increasing statistical power. Another explanation could be that the analysis was conducted on all participants regarding psycholinguistic parameters despite some having anomia related to lexical access difficulty (80% of HC and 60% of MCI), which is usually associated with an impact of the frequency, while the rest had anomia related to semantic deterioration (80% of AD and 40% of MCI), which is usually associated with an impact of other psycholinguistic parameters such as category. The absence of a category effect contrasts with the results of some studies. For example, several authors reported greater difficulties in naming for biological objects compared to manufactured ones in individuals with AD or MCI (Callahan et al., 2015; Duong et al., 2006; Fung et al., 2001; Taler et al., 2016; Whatmough et al., 2003). However, other studies also have revealed the absence of a category effect on naming, as in the current study (Laws et al., 2007; Lockyer, Sheppard, & Taler, 2015).

The efficacy of phonological cueing to facilitate naming in the three groups is consistent with previous studies (Balthazar et al., 2008; Willers et al., 2008) and could suggest a lexical origin for anomia. However, it was impossible to determine if the cues had a significant influence on naming performance.

Functional Origin of Anomia

The cognitive model proposed by Caramazza and Hillis (1990) suggests that the type of naming errors is determined by the functional origin of the impairment. When all participants were considered, the error patterns, the efficacy of cueing, and the influence of psycholinguistic parameters did not point in a clear direction to the functional origin of anomia since manifestations of both lexical and semantic impairment were found. Therefore, a separate individual analysis was conducted for each participant to see if the unclear group profile could result from the combination of two distinct individual profiles, namely lexical and semantic. This hypothesis was confirmed by the individual analyses. For some participants, the semantic system seemed to be the main cause of anomia (n = 15), while for the others, the phonological output lexicon and its access appeared as the principal cause (n = 25). More interestingly, the main origin of anomia varied among the three groups. For HC participants, the origin of the observed anomia was mostly lexical (80%), while a more combined lexico-semantic origin was identified as the possible cause of anomia for three HC participants. This result is in line with literature showing that semantic knowledge is well preserved in healthy aging (Piolino, Desgranges, Benali, & Eustache, 2002). In the MCI group in the present study, results were mixed with anomia

being caused by an impairment of lexical access for most of the participants (60%) and by an impairment of the semantic system for 40%. In the literature, results were also inconsistent, with some studies suggesting a semantic origin (Adlam et al., 2006; Joubert et al., 2010; Willers et al., 2008), and others a lexico-semantic origin (Balthazar et al., 2008; Duong et al., 2006; Guidi et al., 2015; Taler & Phillips, 2008) of anomia in people with MCI.

According to the individual analyses performed in the current study, this inconsistency found in previous work could be explained by the presence of two distinct profiles. In this study, participants in the two subgroups (i.e., lexical impairment/semantic impairment) did not differ in age, education, and general cognitive functioning assessed by the MoCA. Thus, age, level of education, and general cognitive functioning could not predict the profile found for a participant. Future studies should focus on understanding the differences between those two subgroups with regard to other cognitive functions, evolution, and prognosis in order to allow for more effective and accurate interventions at all stages of the disease. Finally, in the AD group, an impairment of the semantic system was identified as the main cause of anomia for 80% of the participants, which is in line with the study by Lin et al. (2014) in which a progressive degradation of the semantic system was responsible for anomia in AD. However, it is noteworthy that for the participants in the present study, the succinct objective assessment of the semantic system (with the Pyramids and Palm Trees Test) showed no semantic deficit. The Pyramids and Palm Trees Test did not seem to be sensitive enough to objectify difficulties in the access or retrieval of fine and distinctive semantic features that could be at the origin of anomia in the AD group as suggested by Lin et al. However, these results must be interpreted carefully given the very small AD sample in this study.

Nevertheless, the idea that anomia is caused by difficulties to access or retrieve the distinctive semantic features within the semantic memory is well documented in AD. Indeed, according to many researchers, distinctive semantic features would be more vulnerable to pathology than general semantic features shared by several concepts (Catricalà et al., 2015; Flanagan, Copland, van Hees, Byrne, & Angwin, 2016; Garrard, Lambon Ralph, Patterson, Pratt, & Hodges, 2005; Laisney et al., 2011). For this population, the primacy of coordinate semantic paraphasias could therefore be explained by a gradual deterioration of these distinctive semantic features, thus resulting in a difficulty to differentiate two close concepts belonging to the same category because of unclear semantic representations (Catricalà et al., 2015; Garrard et al., 2005).

Strengths and Limitations

The present work has some limitations, the most important being the small number of participants, especially for AD. Even though statistical analyses accounted for these small sample sizes, the results regarding the origin of anomia must be interpreted carefully. Moreover, the small samples may have hidden differences among the three groups regarding sociodemographic variables. Similarly, even though the oral naming task had 260 images, participants made errors on only 98 of them, lowering the statistical power of the study regarding psycholinguistic parameters. Therefore, it is crucial that those results are replicated with larger sample sizes, but this study is yet an important step towards the understanding of anomia in pathological aging. Also, participants included in the study had a mean education of 15 years, which is not representative of the older adult population. This may have influenced the preservation of their naming capacities (Reis, Guerreiro, & Castro-Caldas, 1994).

Finally, it is likely that the semantic cues were not precise enough to help naming in the case of an anomia caused by difficulties in access or retrieval of specific and distinctive semantic features. Even though the semantic cues were created systematically and administered rigorously (all participants received the exactly same cues in the same order and the same moment), they were about semantic features most commonly associated with the target word, which leads in some cases to a lack of precision to help naming. For example, for the word *apple,* the semantic cue was "red fruit." Although suitable, this cue also corresponds to the target words cherry, strawberry, and raspberry. A more specific semantic cue could have been beneficial, such as "red fruit picked from the trees in autumn." Another possibility could have been to propose to all participants a semantic survey targeting the failed items.

This study also has significant strengths. First, the exclusion of participants with visual agnosia was a significant strength, despite its impact on the sample size and statistical power. Indeed, the qualitative analysis of errors usually makes it impossible to determine whether the origin of visuosemantic errors is visual or semantic. By excluding participants with difficulties in visual recognition, we can hypothesize that their origin was generally semantic. Moreover, the exclusion of participants with probable visuoperceptual difficulties is fundamental when the experimental task uses images. In the same line, the assessment of the semantic system with the Pyramids and Palm Trees Test allowed a more nuanced interpretation of the naming performance, as explained earlier. Second, many factors allowed us to minimize the risk of errors or bias in the qualitative analysis of the results, such as the

use of an exhaustive classification of naming errors, the rigorous selection of semantic and phonological cues, the standardized administration of the task, and the use of audio recordings to analyze more finely the types of errors.

Clinical Implications and Future Perspectives

The clinical relevance of the present study is based on two main findings: (a) individuals with MCI commit relatively few naming errors despite the fact that anomia is a core element of the cognitive complaint and (b) naming difficulties found in HC and anomia observed in MCI and AD has a different origin, and two distinct profiles are found in MCI. By specifying the functional origin of anomia in MCI and AD, this study is the preliminary step in developing cognitive interventions specifically targeting the naming difficulties of these populations. In MCI, the present results highlight the importance of an appropriate individual assessment prior to intervention in order to determine the functional origin of anomia since distinct profiles (i.e., lexical or semantic or a combination of lexico-semantic) can be found. In our study, the Pyramids and Palm Trees Test, which assesses semantic processing for functional and encyclopedic knowledge of the target words, did not seem to be sensitive enough to objectify difficulties in the access or retrieval of fine and distinctive semantic features, yet observed in participants with AD and 40% of participants with MCI. Therefore, the development of a more extensive and comprehensive battery to assess semantic memory would be extremely relevant, especially since no battery is actually adapted to the French-Québec population.

In addition, interventions aimed at reducing anomia in AD should target the impaired access to semantic knowledge or the compensation of the degradation of this knowledge in the semantic system. Furthermore, even though the exclusion of patients with visuospatial impairments was a strength of the study, considering that it is usual to have visuospatial impairments within AD, it would be important to conduct studies aiming to describe the specific needs of such patients in terms of language or anomia rehabilitation. Moreover, it would be important to develop other tests to evaluate the semantic system without using a pictographic entry. Until now, cognitive interventions developed for individuals with MCI mainly focused on deficits of episodic memory (Jean, Bergeron, Thivierge, & Simard, 2010; Reijnders, van Heugten, & van Boxtel, 2013; Simon, Yokomizo, & Bottino, 2012), working memory (Hyer et al., 2016), and executive functions (Mowszowski, Lampit, Walton, & Naismith, 2016). An intervention specifically targeting word-finding difficulties could potentially slow the worsening of this deficit during the decline that leads an individual with MCI to the dementia phase of AD.

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Authors' Note

Correspondence concerning this article should be addressed to Laura Monetta, CERVO, Brain Research Centre, 2601 de la Canardière, room F-2400. Québec, QC, G1J 2G3, Canada. Email: laura.monetta@rea.ulaval.ca

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