Word-word Relations in Dementia and Typical Aging

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Abstract

ssssss Older adults tend to suffer a decline in some of their cognitive capabilities, being language one of least affected processes. Word association norms (WAN) also known as free word associations reflect word-word relations, the participant reads or hears a word and is asked to write or say the first word that comes to mind. Free word associations show how the organization of semantic memory remains almost unchanged with age. We have performed a WAN task with very small samples of older adults with Alzheimer's disease (AD), vascular dementia (VaD) and mixed dementia (MxD), and also with a control group of typical aging adults, matched by age, sex and education. All of them are native speakers of Mexican Spanish. The results show, as expected, that Alzheimer disease has a very important impact in lexical retrieval, unlike vascular and mixed dementia. This suggests that linguistic tests elaborated from WAN can be also used for detecting AD at early stages.

1 Introduction

According to the World Health Organization (2015), aging is a process associated with molecular and cellular damage, which leads to a general decline of the person and, eventually, its death. Among the changes caused by age, some degree of cognitive decline is commonly observed in older adults, and the proportion of elderly people who suffer this decline increases (Rog and Fink, 2013). This decline has been measured through neuropsychological evaluations, which have shown two common profiles in elderly people, those who present successful aging, meaning a proper execution in cognitive tasks, as well as in daily life, and those who present cognitive impairment (Ardila and Rosselli, 2007) or neurocognitive disorders according to the DSM-5 (American Psychiatric Association, 2013).

As mentioned before, aging causes a general decline in elderly people, which can be observed at anatomical and physiological levels and it is intimately linked to cognitive and emotional changes (Cummings and Benson, 1992). During senescence, a decrease in memory capacity and learning is representative of the cognitive profile exhibited, showing a pattern in which forgetfulness rate increases within the fifth decade of life, while their learning ability is decreased, characteristics that will progress slowly through time and will give us cues of pathology, especially in people with dementia, where this process will be particularly accelerated (Ardila and Rosselli, 2007).

Elderly people show more alterations in episodic memory than semantic memory, especially when the memories need more effort to be remembered (consciousness) than those performed automatically and based in familiarity. In addition, it is also known that age affects the process of codification, especially when strategic thinking is needed, and the recovery process, where the use of cues is required to recall information. Finally, it is common that elderly people show problems in context memories, meaning the context in which an event was developed, rather than content memory, meaning the memory of the event, while prospective memory, meaning the ability to remember future events (e.g., remember to do something or going somewhere), also is affected due to a lack of accessibility to internal cues and auto initiated processes (Jurado et al., 2013).

On the contrary, the least affected cognitive process by aging is language, a process that has shown improvement throughout life, especially in items such as vocabulary. Nonetheless, this process can be

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affected by other elements of cognition, such as memory, which can cause phonologic recovery of words, provoking anomia commonly known as "tip of the tongue phenomenon" (Jurado et al., 2013).

The problem is very relevant for linguists, because approaching the different types of anomias caused by illness can help to describe how words are connected in the lexicon. Moreover, there is a lack of description of the specific language difficulties associated with different illnesses and their stages. To do that, we propose a Word Association Norms (WAN, from here) approach, that understands lexicon as linked data, being the change in the of the links the best way to explain the cognitive deterioration. Having more information about this would help linguists and cognitive scientists to model a theory of memory.

The present research aims to investigate the type of semantic relationships generated by seven patients with dementia and their typically aging peers, matched by sex, age and years of education.

From here, our paper is structured as follows. Section 2 introduces a psychological description of the types of dementia that we are approaching. Section 3 some basic ideas on Word Association Norms are provided, as well as their relevance for linguistics, psychology and computer science. In 4, we explain the experiment, whose results are presented at 5. We finish the paper with the discussion and future work perspectives at 6.

2 Alzheimer's Disease, Vascular Dementia and Mixed Dementia

The information obtained about the cognition and lifestyle in elderly people has shown great importance in the establishment of criteria to diagnose neurocognitive disorders such as dementias- and their origin, as cognition has specific variations according to the origin of each disorder. In pathological aging the severity of an impairment, both physical and cognitive, can interfere in various ways in the family, social and occupational functioning of the subject. The most serious level of pathological aging is known as dementia (Portellano, 2005). Dementia is a syndrome due to a brain disease, usually of chronic or progressive nature, which can alter multiple superior cortical functions, also, all alterations in cognitive function are accompanied by a deterioration of emotional or social control, as well as behavior or motivation (Jurado et al., 2013). All types of dementia involve mental decline that (Alzheimer's Association, 2006):

- occurred from a higher level (for example, the person didn't always have a poor memory)
- is severe enough to interfere with usual activities and daily life
- affects more than one of the following four core mental abilities
  - recent memory (the ability to learn and recall new information)
  - language (the ability to write or speak, or to understand written or spoken words)
  - visuospatial function (the ability to understand and use symbols, maps, etc., and the brains ability to translate visual signals into a correct impression of where objects are in space)
  - executive function (the ability to plan, reason, solve problems and focus on a task)

Alzheimer's disease (AD) and vascular dementia (VaD) are the two most common forms of dementia (Formiga et al., 2008). AD is characterized by the formation of plaques of the amyloid beta protein which produces neuronal death (Quiroz Baez, 2010). In VaD, various cognitive alterations are caused by cerebrovascular diseases (Portellano, 2005). Mixed dementia (MxD), for example, is believed to be caused by Alzheimer's disease in combination with some cerebral vascular disease; it represents between 13 and 17% of cases worldwide (Cervantes et al., 2017).

At present, our society experiences an increase in the numbers of years that people live. Although many benefits, this increase also implies an increase in physical illnesses and cognitive deterioration. Dementia is one of the illnesses that increases its presence as people get older. One of the areas that is frequently affected is language. Language problems in dementia tend to be detected when they are notorious. By that time, there is very little that can be studied or even ameliorated. Thus, it is essential to evaluate language skills at the early stages of dementia or at least as early as it is diagnosed.

3 Word Association Norms

Word association (WA) tests are an experimental technique for discovering the way that human minds structure knowledge (De Deyne et al., 2013). In a free word association experiment, the participant reads or hears a word (*stimulus*) and is asked to write or say the first word that comes to mind (*response*) (Hirsh and Tree, 2001). Free WA tests are able to produce rich types of associations that can reflect both semantic and episodic memory contents (Borge-Holthoefer and Arenas, 2009).

Word Association Norms (WAN) are collections of WA taken in different populations. From these collections some measures can be studied. The most frequent word provided as the output of a given input word is considered as being the first associate (FA). The strength of association of the first associate, that in the paper is referred as AS, represents the proportion of participants who responded with the same first associate. This, among other measures, such as total of associates (number of different answers given), idiosyncratic answers (answers given by only one participant in the whole sample), blank answers (words to which the participant didn't give any answer in the established period of time) are calculated to understand how connected a lexical network is for a group of participants with similar background (Callejas et al., 2003; Salles et al., 2008).

From the many experiments performed in many languages, it has been concluded that there is uniformity in the organization of associations and people shared stable networks of connections among words (Istifci, 2010).

We performed a Word Association Norms (WANs) task, also known as free word association task. WANs are generally taken in young healthy adults, generally, university students. Comparisons between young and old adults have increased our understanding about the potential effects of aging on deficits in the lexical network. Generally speaking, comparisons between WANs produced by young and old adults allow us to conclude that there is very little change in the organisation of semantic memory with age, at least in word associations (Burke and Peters, 1986; Tresselt and Maizner, 1964). It has been found that in old adults, the connections in the semantic network are abundant and resistant to deficits (D.G. MacKay, 2001). For example, an overlap of 60.5% in the three most frequent responses between young and old adults was reported by Burke and Peters (1986). Moreover, these authors retested 2 to 3 months later part of their study with a subsample from the original and found that both, young and old adults were consistent in providing the same first associate for word pairs with a high strength of association than with low strength of association, arguing that old adults do not seem to have a retrieval problem as they were generating in an automatic fashion their responses which were stored in semantic memory. Hirsh and Tree (2001) also reported an overlap of 60% between the top three responses of a group of British young and old adults.

In contrast, research has reported changes in the semantic network exhibited by adults with neurological diseases. Kent and Rosanoff (1910) tested 100 words with the participation of 1000 normal subjects as well as 247 participants with a mental disease dementia praecox, paranoic conditions, manic-depressive states, epilepsy, among others finding some tendencies about a gradual, but not an abrupt change from a normal mental state to a pathological one.

Borge-Holthoefer and Arenas (2009) established a relation between cognitive illness and the capability to walk the graph or our semantic relations. This difficulty could come from the degradation of the graph, this is the weakening of the links between the words. Following this hypothesis, it is a key aspect of the research to establish the weight of the regular connections in contrast with the ones showed by patients with dementia.

According to Clark (1970), the rules of relationship words from free association are based on syntagmatic and paradigmatic relations. Through this traditional classification, paradigmatic responses belong to the same grammatical class of the stimulus words and they are generally similar words in conceptual terms because they share some semantic features (e. g., dog-cat, white-black, eat-drink). While syntagmatic responses belong to a different grammatical category of the stimulus words, which might appear next in the same sentence (e. g., house-large, high-giraffe, walk-slowly). Thus, older adult speakers of English show greater variability in word association unlike young adults, also it has been found that they tend to provide a greater amount of paradigmatic responses (Burke and Peters, 1986; Lovelance and

Cooley, 1982). In contrast to these findings, research with German has reported a decrease in the emergence of paradigmatic responses (K. Riegel and R. M. Riegel, 1964). Most researches focused on this population concluded that a dominant emergence of paradigmatic responses in word association tasks exists.

Changes in the predominance of paradigmatic or syntagmatic responses are observed in dementia. Gewirth et al. (1984) reported that participants with dementia or aphasics tended to provide paradigmatic responses for nouns and adjectives and syntagmatic for verbs and adverbs. Although the mechanism producing syntagmatic responses were similar to normal patients, paradigmatic responses were less efficient in dementia and more random producing then more idiosyncratic responses. Also, dementia patients tended, more than aphasic or normal adults, to perseverate responses. Eustache et al. (1990) showed that as the severity of dementia increased, AD patients were less likely to give a frequent response. Recently, Preethi and Goswani (2016) showed reduced levels in the first association strength in a word association task of participants either with dementia or aphasia, but not in neuro-typical participants. Interestingly, paradigmatic responses were significantly more affected than the syntagmatic ones. Gollan et al. (2006), as in Gewirth et al.s study, also reported a semantic deficit in AD patients depending on the type of word. Differences between controls and AD patients were found for strong associated stimuli (e.g., bride-groom), but not for weak stimuli (e.g., bride-pretty): AD participants generated less common responses for the strong, but not the weak stimuli. Gollan et al. argued that weak associations are less semantic, and thus less dependent on meaning.

At present, little is known regarding the potential differences in a semantic deficit that may be encountered in AD patients as opposed to other dementias. The current work aimed to compare Alzheimer, mixed and vascular dementia.

4 Method

4.1 Participants

In this study 14 elder adults participated. Half of the participants had dementia and the other half was the control or healthy- aging group. Dementia group included participants with Alzheimer's disease (n = 2) phase one and two, Vascular (n = 3) and Mixed Dementia (n = 2). All of them had previously received the diagnosis from their physicians. The group consisted in 3 men and 4 women, its mean age was 78.29 years age span was 67 to 85 years old, and the education average 9.28 years. The healthy-aging group no neurological diseases was formed equivalent as possible in sex, age and years of education to the Dementia group. Its mean age was 78.14 years (age span 67 to 85 years old) and the average years of schooling was 9.33 years.

It is important to emphasize that participants selected for the sample were only those whose dementia progression did not show impairment in most of their daily life basic skills (e.g. toileting or feeding) according to their physicians and caregivers. It was also taken into consideration their ability or willingness to finish the word association task, causing a significant reduction of the sample. However, as they were paired with controls through age, gender and educational degree criteria and exclusively compared with the group that constituted their paired controls, this work can be taken into account as a case-control study, until more participants can be included to generalize results.

Although our sample does not permit the generalization of the results, it allows researchers to have an insight about the language changes that take place as a result of each type of dementia and effect of other variables. However, in the case of vascular dementia results (such as lack of FA) can be determined by the cause or the region affected by the cerebrovascular accident, having a different effect on cognition that should be taken into account in future studies with a sample that can allow dividing participants in subgroups.

4.2 Procedure

Participants performed a free-word association task in which 120 familiar and frequent words in Spanish were orally presented, one-by-one, by an experimenter who manipulated the laptop in which an application presented the input words in a previously set-up order. The experimenter wrote in a computer

the participants answers. If after 30 seconds, the participant remained in silence, the experimenter who received an automatic visual notification after 30 seconds repeated orally once more the input word. If after another 30 seconds, the patient did not produce an answer, the system automatically exhibited the following word. If the participant did not produce an answer for three consecutive input words, the experimenter repeated the instructions and continue with the task.

4.3 Data analysis

The application stored the answers written by the experimenter for further analyses. Initially, two experimenters edited the data so that there were no language errors in the answers, for example, orthographical mistakes. The experimenters also unified the responses using a lemmatization process. In Spanish a contrast between masculine and feminine exists, where some words in feminine tend to end in a and in masculine in o. Thus, the answers were unified to the masculine ending (niño, niña was unified to niño). In the same way, every verbal form has been unified to the infinitive.

Later, an analysis of the lexical relation between every *stimulus* and its FA was carried out. Every pair was labelled as a paradigmatic or syntagmatic relation, following the definition given by (Clark, 1970).

5 Results

An analysis with some of the conventional measures reported in word association norms was performed, including the association strength of the first associate (AS), number of blank answers (BA), and mean response time (RT) taken to provide the first associate.

For every *stimulus* the values AF and RF are calculated. AF, *absolute frequency* refers to the absolute frequency of syntagmatic and paradigmatic responses. RF, *relative frequency*, retrieves the percentage relation between syntagmatic and paradigmatic responses.

The AS, *association strength* of the FA, first associate, to every stimulus has also been obtained, with the following formula: being N the total number of answers in the sample for a stimulus word, and F the frequency of a given response

$$AS = \frac{F * 100}{N}$$

With the aim of evaluating if the means AS (association strength of the first associate), BA (blank responses), and RT (response time) provided by each of the three experimental groups (AD, MxD and VaD) were significantly different to their control groups, we performed a series of comparisons.

With the aim of evaluating if the means AS (association strength of first associate), BA (blank responses), and RT (response time) provided by each of the three experimental groups (AD, MxD and Vad) were significantly different to their control groups, we performed a series of mean comparisons.

5.1 Statistical Results

Each type of dementia was compared with their control group through t-tests for independent measures. In the comparison between the group diagnosed with AD and their respective controls for AS significant differences were observed between both groups ($t(234) = -4.17$; $p < 0.005$), where the group with AD presented less strength in their FA (0.08 ± 0.4) than the control group (0.44 ± 0.83). Also, the comparison between MxD and their control group for the AS of the FA showed significant differences between both groups ($t(234) = -3.34$; $p = 0.001$), where the control group presented a higher associate strength (0.76 ± 1.05) than the group with MxD (0.35 ± 0.8). Finally, the group diagnosed with VaD did not provide a common FA because the responses as FA were different, thus their association strength was null. This lack of associate strength is significantly different when compared with their control group ($t(234) = -4.589118$; $p < 0.005$), where the control group did present common first associates (0.3 ± 0.72). For blank answers (BA), significant differences between the AD and the control group were encountered ($t(234) = 14.02$; $p < 0.005$), where the AD group presented blank answers (0.62 ± 0.48) but the control group didn't. Non-significant differences were found between MxD and controls ($t(234) = 0.85$; $p = 0.39$), where MxD presented a slightly higher number of BA (0.06 ± 0.25) than the control group (0.04 ± 0.20). Both, the VaD and controls showed a lack of BA. Finally, in the case of reaction times

	AS	BA	RT
AD	0.08± 0.4	0.62± 0.48	11.57± 8.22
CG	0.44± 0.83	0	5.92± 2.79
MxD	0.35± 0.8	0.06± 0.25	4.67± 2.27
CG	0.76± 1.05	0.04 ± 0.20	5.57± 2.23
VaD	N.D.	N.D.	4.96± 2.1
CG	0.3± 0.72	N.D.	4.51± 1.69

Table 1: Comparative strength between AD, MxD, VaD and their respective control groups in AS, BA and RF.

	AS		BA		RT	
	t(234)	p	t(234)	p	t(234)	p
AD vs CG	-4.17	< 0.005	14.02	<0.005	7.05	<0.005
MxD vs CG	-3.34	0.001	0.85	0.39	-3.08	0.0023
VaD vs CG	-4.58	<0.005	N.D.	N.D.	1.77	0.07

Table 2: t-tests performed comparing AD, MxD, VaD and their respective control groups in AS, BA and RF.

(RT), significant differences between the AD group and their controls were observed ($t(234) = 7.05$; $p < 0.005$), where the AD group took more time to give an answer (11.57 ± 8.22) than the control group (5.92 ± 2.79). Similar results were found between MxD and controls ($t(234) = -3.08$; $p = 0.0023$), where the group with MxD took more time to elicit a response (4.675706 ± 2.271421) than the control group (5.57 ± 2.23). Conversely, non-significant differences were encountered between the VaD and control groups ($t(234) = 1.77$; $p = 0.07$), RT for the VaD group (4.96 ± 2.1) and their control group (4.51 ± 1.69). Tables 1 and 2 can help to visualize the results.

To determine differences between dementia groups, an univariate ANOVA was done with groups AD, MxD and VaD as factors. This ANOVA determined statistically significant differences for AS between groups ($F(2) = 15.199$, $p < 0.05$). Post-hoc tests using Bonferroni corrections showed that the MxD group AS was higher ($M = 0.35$, $SD = 0.8$) than that for the AD group (M=0.0847, SD=0.40459) and VaD group (no AS generated). Meanwhile for BA, the univariate ANOVA showed significant differences ($F(2) = 139.970$, $p < 0.05$) between AD and the other groups, where AD had more BA ($M = 0.62$, $SD = 0.48$) than MxD ($M = 0.06$, $SD = 0.25$) and VaD (no BA were provided). Finally, the ANOVA for RT showed statistically significant differences ($F(2) = 69.737$, $p < 0.05$) where Bonferroni correction showed that AD group had a slower reaction time ($M = 11.57$, $SD = 8.22$) than MxD ($M = 4.67$, $SD = 2.27$) and VaD ($M = 4.96$, $SD = 2.1$).

5.2 Syntagmatic and Paradigmatic relations

With the responses provided by the participants (94.8%) a classification according to the type of relationship between the stimulus and its response was carried out. The classification took into account syntagmatic and paradigmatic relations (Clark, 1970), as well as unclassifiable responses (e. g., idiosyncratic responses or onomatopoeias). Overall, the participants showed a higher proportion of paradigmatic responses (51.63%), followed by the syntagmatic responses and unclassifiable responses (47.42% and 0.94%, respectively). Table 5.2 presents the Absolute frequency (AF) and Relative frequency (RF) for both paradigmatic and syntagmatic responses. AF refers to the total number of responses and RF to the proportion (calculated by dividing the AF by the total number of cases) from participants with AD, MxD, VaD, and their respective control groups.

The AD group and control group differed in the proportion of paradigmatic and syntagmatic responses

	Paradigmatic		Syntagmatic		Unclassifiable	
	AF	RF	AF	RF	AF	RF
AD	51	30.91	107	64.85	7	4.24
CG	148	61.67	89	37.08	3	1.25
MxD	197	55.81	156	44.19	0	0.00
CG	181	50.99	173	48.73	1	0.28
VaD	119	49.79	117	48.95	3	1.26
CG	126	52.50	113	47.08	1	0.42

Table 3: Frequency of paradigmatic, syntagmatic and unclassifiable responses per group: AD, MxD, VaD, CG (control group).

generated. Most responses of the AD participants were syntagmatic (64.85%), followed by paradigmatic (30.91%), whereas those in the control group had a higher amount of paradigmatic responses (61.67%), followed by syntagmatic (37.08%). The results showed significant difference between the type of responses for both groups χ^2 (2, N = 4) = 37.95, p = 0.00000001. With respect to older adults with MxD, they showed a discrete higher proportion of paradigmatic responses (55.81%) as the control group (50.99%), syntagmatic responses in both groups were 44.19% and 48.73%, respectively. Non-significant differences were encountered χ^2 (2, N = 6) = 2.55, p = 0.28. Finally, the VaD group and the control group had similar percentages of paradigmatic (49.79% and 52.50%, respectively) and syntagmatic responses. Non-significant differences in paradigmatic responses were found between the two groups (χ^2 (2, N = 4) = 1.26, p = 0.53). As it can be seen, groups of participants with MxD and VaD dementia do not differ from their controls in the type of response provided. However, there are significant differences between groups -AD, VaD, and MxD- in the relationships they established χ^2 (4, N = 7) = 39.50, p = 0.0000001. Those differences are mainly due to contrasts between the AD group and the other two groups MxD and VaD.

6 Discussion

Quantitative results suggest the existence of difficulties to access the lexical semantic memory in participants with dementia, illustrated by the higher quantity of first associates produced by the control group (typically aging group). The difficulties in processes that access lexical memory have been previously studied in typically aging people (Rabadán et al., 1998) and participants with dementia, showing in both groups progressive language problems which onset is present at an early aging-stage (Jaramillo, 2010). We also found differences in the participants' responses according to the type of dementia. The number of AS was higher in MxD compared to AD, while the VaD group showed a lack of associate strength consistent with evidence of greater deficits on semantic memory in this group (Graham et al., 2004).

Similarly, deficits were found when blank answers were analyzed, especially in the groups diagnosed with AD and MxD. This kind of deficits have been previously observed in tasks such as category fluency, confrontational naming task and similarity judgments tasks; therefore, some authors affirm that they are the result of the alteration of semantic memory, which affects the meaning of words, concepts and facts (Jurado et al., 2013).

Furthermore, the increase of reaction times was higher in the groups diagnosed with AD and VaD, which can be related to a decrease in processing speed. Salthouse (1996) and Salthouse et al. (2002) propose that the variance of times observed in almost all cognitive tasks can be explained through the generalized decrease of processing speed. A consequence of the initial decrease in processing speed in complex tasks is to prevent the person to rely on the necessary information to complete the next phase of the task, which could be related to the performance in the task, especially to the number of blank answers produced by the AD and the MxD groups.

Regarding the type of lexical relationships, a greater proportion of paradigmatic responses was ob-

served in both groups of participants with MxD and VaD and their typically-aging peers. Our results follow the same dynamics reported in previous research with neuro-typical older adults. Also, the data of this research agree with the findings about the preference for paradigmatic associations in the population of older adults with typical aging (Lovelance and Cooley, 1982; Burke and Peters, 1986). In contrast to other research (Gewirth et al., 1984; Preethi and Goswani, 2016), the paradigmatic responses of the participants with MxD or VaD were not affected. In this sense, it can be inferred that mixed and vascular dementia do not affect the type of lexical relationships that often predominate in older adults. However, in the case of participants with AD a different phenomenon was observed. Syntagmatic responses were generated in greater proportion, similar to the types of responses provided by young children children younger than 8 years (Ervin, 1961; McNeill, 1970).

The current results indicate that AD causes a change (or regression) in the type of lexical relationships provided by participants. Changes in lexical associations might be taken as a predictor of AD. It seems that, according to this results, a new way for detection of Alzheimer could be developed, based on the types of associations that the patients retrieve. Usually, the strength in the FA is considered to be a good indicator for Alzheimer, but this feature is difficult to test when only one user is compared to a large sample. However, the tendency to provide more syntagmatic than paradigmatic word associations can be a first clue to determine AD. This should be an important line of research to be developed in the future. On the other hand, it would be very interesting to understand how other types of dementia affect word retrieval and the organization of memory. It would be worthwhile to expand the sample to confirm that the presence of these specific conditions does not change the pattern of response.

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