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To what extent does the mental lexicon differ between healthy aging individuals and in patients with semantic dementia?

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1. Introduction

The aim of this paper is to evaluate the comprehension and production of (concrete and) abstract words in typically aging individuals as compared with patients suffering from semantic dementia. Human aging is a naturally occurring biological process which brings physiological and psychological changes in a person's life, leading to senescence. On a physiological level, the biological functions and the adaptability to metabolic stress gradually decline. On the psychological level, cognitive abilities are increasingly impaired, the most common manifestations being memory problems and longer reaction times, both in verbal and non-verbal tasks (Encyclopædia Britannica, 2017). These features can be more severely impaired in the case of neurodegenerative diseases which cause accelerated atrophy of the brain, such as dementia. In the linguistic form of semantic dementia, the semantic knowledge (the meaning of concepts) is particularly impaired. This aspect is the central topic of this paper, around which the following questions will be analyzed:

- In which regions of the brain are concrete and abstract words represented?
- How does brain damage specific to SD impact semantic knowledge?
- What similarities exist between the mental lexicon of healthy aging adults and that of patients with SD?
- Are concrete words and abstract words processed similarly in the brain, respectively by healthy aging individuals and by SD patients?
- Are there specific concepts or categories that are impaired due to either healthy aging or degenerative brain atrophy?

To answer these questions, the available literature up-to-date on this subject will be reviewed. First of all, the mental organization of words (mental lexicon) and their representation in the brain will be explained in Chapter 2. Chapter 3 will provide more detailed information about semantic dementia. Chapter 4 will provide a comparative evaluation of the semantic knowledge in healthy aging individuals and in patients with SD, divided in two sections: concrete words and abstract words, including reverse concreteness effects. In the conclusion the insights from the selected studies will be summarized and open research question will be addressed.

2. The mental lexicon

A lexical concept is "a unit that integrates the multifarious semantic features that constitute the meaning of a particular word" (Kemmerer, 2015:148). The features associated to each word include phonological representation (i.e., how the word sounds and is pronounced), lexical representation (i.e., how the word is spelled), syntactical knowledge (i.e., how the word is used in sentences), semantic knowledge (i.e., multiple meanings of a word), and a visual representation (i.e., an image of the concept). There are two main categories of lexical concepts: concrete (e.g. *dog*) and abstract (e.g. *freedom*). All lexical concepts that are learned throughout life are stored in the mental lexicon, as part of the semantic memory which includes the permanent representation of an individual's knowledge about the world and cultural experiences. This type of memory is acquired early, is overlearned, and is resistant to degradation except in extreme circumstances, such as brain atrophy or damage. Semantic memory manages the process of recognizing objects, accessing their names and meaning, and converting that knowledge into the right words for speaking (Chertkow/ Bub, 1990:397). Word processing can be influenced by three factors: frequency (i.e., how often a word is used), familiarity (i.e., to what extent an individual knows the meaning of a word), age of acquisition (i.e., the age at which the word was learned). Words are characterized in terms of concreteness (i.e., "the directness with which words refer to concrete entities" (Kemmerer, 2015:351)) and imageability (i.e., "the ease and speed with which words elicit mental images in various modalities" (Kemmerer, 2015:352)). These two features have different semantic representations: concreteness is bimodal, "capturing the categorical ontological distinction between concrete and abstract concepts, whereas the distribution of imageability ratings is unimodal, indexing the graded amount of sensory (primarily visual) associations of words" (Vigliocco, 2014:1768).

2.1 Neural representation of concrete words

Numerous studies have tried to underpin the brain areas in which abstract and concrete words are represented using brain imaging methods. The most common are functional magnetic resonance imaging (fMRI) which measures the blood oxygenation level dependent (BOLD) signal (increased brain activity requires more oxygenated blood), and positron emission tomography (PET) which measures “regional cerebral blood flow–and, by inference, regional neural activity–by tracking the distribution of a radioactive isotope throughout the brain” (Kemmerer, 2015:44).

Wang et al. (2010) conducted a meta-analysis of 19 fMRI and PET studies on 303 subjects which reported different representation of concrete and abstract words: some studies found greater brain activity for concrete words, predominantly either in the left hemisphere, in the right hemisphere, or equally in both; in contrast, other studies found greater activity for abstract words; yet other studies found bilateral neural activity for both abstract and concrete words. The meta-analysis revealed greater activity for concrete words in the posterior cingulate, precuneus, fusiform gyrus, and parahippocampal gyrus (Wang et al., 2010). The anterior temporal lobes (ATL) are also essential for representing objects encoded by concrete nouns (Kemmerer, 2015:343).

2.2 Neural representation of abstract words

Regarding abstract words, the meta-analysis conducted by Wang et al. (2010) showed that the inferior frontal gyrus and the middle temporal gyrus in the left hemisphere are more active for abstract words. Overall, the meta-analysis revealed greater activation of the verbal system for abstract words and greater activation of the perceptual system for concrete words.

The left middle/ superior ATL has been found to play a bigger role in the processing of abstract words. This finding is based on the observation that if the anterior middle temporal gyrus of healthy individuals is disrupted through repetitive transcranial magnetic stimulation (rTMS), their semantic processing of abstract words is impaired, but the processing of concrete words is not affected. The effect is even stronger if this area is disrupted in the left hemisphere (Kemmerer, 2015:351). These findings indicate that the bilateral ATL support the semantic structure of abstract concepts.

In a more recent fMRI study, Vigliocco et al. (2014) found that concrete and abstract words engaged largely overlapping networks in the left hemisphere, but found no activation in the ATL.

The neural representation of abstract words seems to be influenced by emotional experience, as shown by Vigliocco et al. (2014). The authors conducted an fMRI experiment that revealed greater neural activity for abstract words in the rostral anterior cingulate cortex, a brain area involved in processing emotions. Knowing that generally abstract words are more emotionally loaded than concrete words (e.g., *joy* vs. *hand*), the authors hypothesize that emotional processing is necessary for processing them. They tested 20 healthy young adults on a visual lexical decision task, in which the subjects had to select the word from a series of 60 words (abstract and concrete), pseudowords, and letter strings that were presented on a computer screen. Their reaction times and brain activity were measured in an fMRI scanner. Furthermore, processing abstract words engaged more the rostral anterior cingulate cortex (rACC), a brain region involved in emotion-processing (Vigliocco et al., 2014:1775). Thus the results confirmed the hypothesis and suggest that not only language, but also emotional development is necessary for the acquisition and processing of abstract concepts. This fact supports theories of embodied semantic representations, which posit that concrete words are grounded in the sensory-motor experience, while abstract concepts are grounded in the affective (Vigliocco et al., 2014:1767). However, it is noteworthy that the results might have been influenced by the gender and age of the subjects. The majority were females (16 out of 20) and from a psychological perspective women are generally more sensitive to emotional content in comparison with men. Regarding age, the participants were between 18 and 33 years old, which doesn't allow for a direct application of the findings to older individuals.

In conclusion, concrete and abstract concepts are represented differently in the brain, but the semantic functions of the ATLs involve both word categories.

3. Semantic Dementia

Dementia is a syndrome manifesting in deterioration of memory, thinking, behavior, and ability to perform daily tasks, which affects older individuals, but it is not a typical part of healthy aging. Dementia is caused by injuries (e.g., stroke) or degenerative disease of the nervous system leading to progressive atrophy (i.e., tissue loss) in specific brain areas (Kemmerer, 2015:37). The second most common form of dementia, after Alzheimer's disease, is frontotemporal dementia (FTD), which can take the form of three different clinical syndromes: behavioral frontotemporal dementia (bvFTD), progressive non-fluent aphasia (PNFA), or semantic dementia (SD) (World Health Organization, 2016). The last two linguistic forms are also categorized under primary progressive aphasia (PPA) syndromes, alongside logopenic progressive aphasia (Kemmerer, 2015:93). SD is also called temporal variant FTD (tvFTD) because it is caused by atrophy in the anterior temporal lobe (ATL), mainly the left hemisphere, which in time can progress to the posterior area. The atrophy affects white matter pathways, mainly the inferior longitudinal fasciculus and the uncinated fasciculus (Kemmerer, 2015:104). The ATL is responsible for semantic processing, matching with their meanings (Kemmerer, 2015:26). Consequently, patients with SD have increased difficulty in naming objects and concepts, recognizing them and eventually understanding their use or meaning. They may repeat and speak fluently, but make semantic errors. Damage to the ATLs in SD patients is amodal, so it is not specifically verbal or non-verbal. The degree of verbal semantic impairment seems to be directly correlated with the degree of atrophy and hypometabolism. In time, patients may start manifesting behavioral features of dementia, such as impaired social cognition and emotional regulation (Kemmerer, 2015:101). SD can originate in either brain hemisphere, with different manifestations: atrophy in the right temporal lobe impairs the ability to remember familiar faces, to empathize and understand the emotions of others. Atrophy in the left hemisphere manifests first in semantic impairment (UCSF, 2017). Usually the first signs of FTD (SD) appear between 45 and 60 years old, SD is diagnosed before the age of 65 and lasts on average six years.

4. Semantic knowledge in healthy aging individuals vs. patients with semantic dementia

In this part, healthy aging individuals and patients with SD will be compared in terms of production and comprehension of concrete and abstract words. Similarities and differences in the abilities of each group will be outlined, first for concrete words, and in the second section for abstract words.

4.1 Concrete concepts

Several studies have revealed that concrete words are remembered and recognized more rapidly than abstract words, what is known as the *concreteness effect* (Kemmerer, 2015:337). This effect could be explained by the fact that concrete words are acquired earlier in life, and they are easier to visualize than abstract words (Wang et al., 2010:1459). Generally, the effect is observed both in healthy individuals and in SD patients, but the disease impairs naming performance.

Semantic impairment can be measured with different methods, such as item specificity (i.e., knowing the meaning of specific words), priming and cueing effects (i.e., "verbal or pictorial cues offered to assist the exemplar in tasks such as object naming" (Chertkow/ Bub, 1990:499), by presenting word labels as primes or additional words as cues), and verbal fluency. Chertkow/ Bub (1990) evaluated these three approaches in their study on patients with dementia of Alzheimer's type (DAT). Ten DAT patients with anomia (deficit in naming objects) and a control group with a mean age of 75 were tested with several tasks. The results revealed both similarities and differences in the performance of the two groups. Firstly, healthy aging individuals and DAT patients performed equally in word reading, lexical decision, object decision, word-to-picture matching for mixed category, and spontaneous speech (Chertkow/ Bub, 1990:403). However, the DAT patients scored significantly worse than the controls in several tasks. They had more difficulties in naming objects depicted on picture cards, as compared with controls. They also scored worse in the word-to-picture matching task, where patients were given a word and asked to choose the corresponding picture from a series of five images which were either semantically related or from eight different categories. While they performed worse than the healthy aging individuals in both conditions, they made more errors in the same category task. This indicates that in DAT patients the superordinate categorical knowledge is better preserved than the knowledge of specific concepts. More recent supporting evidence comes from Hoffmann et al. (2014), who evaluated the free speech in an autobiographical interview of seven SD patients (mean age 64) and eight healthy individuals (mean age 60). It was noted that the vocabulary of SD patients consisted of more general words, using category names instead of specific names for objects or concepts. This shows that "as conceptual knowledge declines, speech increasingly consists of general terms that

can be applied in a broad range of linguistic contexts and convey less specific information" (Hoffman, 2014:30).
Furthermore, Chertkow/ Bub (1990) assessed the verbal fluency of the subjects by asking them to name as many words as possible belonging to a specific category or beginning with a specific letter. The quantitative difference between the two groups was significant: the DAT patients were able to produce on average 5.5 words per category, compared with 14.9 from the controls. This result also indicates a categorical impairment.

However, both healthy aging individuals and DAT patients obtained their extreme scores in the same categories: most words for the category *body parts* and least words for the category *tools*. Chertkow/ Bub (1990) explain these results by pointing that body parts are easier to name due to visual cueing, and *tools* is an unfamiliar category for the women tested, who make up the majority of the participants (7 out of 10 in each group). From a neurological perspective, more recent studies have shown that patients with a predominant impairment in tool concepts have intact ventral and medial temporal lobes, but in turn have lesions in the posterior lateral temporal region, inferior parietal region, and/or inferior frontal region, predominantly in the left hemisphere (Kemmerer, 2015:301). The damaged regions are involved in visual-motor processing and these findings indicate that they play a special role in processing tool concepts. This makes sense, considering that the meaning of a tool involves knowledge of how to handle it and would engage visual motor features (Kemmerer, 2015:304). However, other studies have found that words designing body parts are equally difficult to name as are tools, in opposition to the results of Chertkow/ Bub (1990). Based on the more recent findings, the semantic representations of tools and body parts are harder to access than other concepts. Categorical impairment is generally observed in SD patients: their conceptual knowledge of living things (e.g. animals) tends to be more affected than that of non-living things (e.g. tools) (Kemmerer, 2015:299). The results of Chertkow/ Bub (1990) indicate impaired semantic knowledge for specific concepts in DAT patients. The authors of the study assume two possible causes for this impairment: age-related decline in semantic memory or damaged access to the mental lexicon. Based on their results, they conclude that the semantic impairment in DAT patients lies principally in the decline of the semantic memory.

The issue of storage versus access as the underlying problem in semantic impairment has been investigated years later by Stamatakis et al. (2011) with a different approach: they studied the relation between changes in the white matter and word-finding failures in aging individuals, more precisely the tip-of-the-tongue (TOT) effect, experienced when a person is unable to produce a certain word from their mental lexicon. Knowing that this effect becomes more frequent with age and that it is caused by the person's inability to retrieve all the phonological features of the target word in order to produce it, the authors infer that healthy aging may disrupt the basic processes of word retrieval (access to the mental lexicon) and language production (Stamatakis et al., 2011:2), in contrast to Chertkow/ Bub (1990). The authors tested this hypothesis by asking 28 subjects aged between 19 and 82 to name 68 pictures of public persons, then by measuring their white matter with diffusion tensor MRI (DTI-MRI), "a technique used to image, *in vivo*, the distribution of water molecules in brain tissue" (Stamatakis et al., 2011:1). The results confirmed their hypothesis: the frequency of TOT, as well as changes in white matter, were positively correlated with the age of the participants. In subjects who experienced word-finding difficulties, but did not have overall changes in white matter, the analysis revealed altered white matter only in a specific area, the superior longitudinal fasciculus. The authors conclude that this area plays an important role in language production.

Further evidence for difficulties with language production associated with age comes from Verhaegen/ Poncelet (2013), who studied naming and semantic abilities of individuals aged between 50 and 90. The onset age and the cause of naming difficulties are a controversial issue in the literature, and the authors meant to determine whether individuals in their 50s already present naming difficulties, and to test the hypothesis of a language-specific impairment in aging as their cause. For this purpose, the semantic abilities of 120 subjects distributed in the age groups 25-35, 50-59, 60-69, and above 70 years were tested with picture naming and synonym judgment tasks. The authors expected naming and judgement latencies to increase with age. Indeed, the results showed longer reaction times for naming in participants over 50, in addition impaired naming specificity in participants over 60, and semantic impairment in participants over 70. Overall, the results confirmed the age-related decline of semantic abilities, possibly caused by the connections of the language system beginning to weaken in the 50s. The authors conclude that naming difficulties increase with aging due to both linguistic and non-linguistic factors, namely specific language impairment and general cognitive decline (Verhaegen/ Poncelet, 2013:125). The argument of cognitive decline is contradicted by Ramscar et al. (2013). Instead, they claim that the cognitive and linguistic performance decreases with age due to memory search demands, which increases with experience, related to age. In other words, since aged will have learned more concepts in a longer time span, it would take them longer to access the right word in a richer mental lexicon.

4.2 Abstract concepts

Knowing that the organization of abstract and concrete words overlap in the ATLs, the brain area that is damaged in SD patients, and that the middle/ superior part of the left ATL is more involved in processing abstract words (Wang et al., 2010), it is predicted that SD patients have difficulties with both concrete and abstract words, and even more with abstract, depending on the origin and progression of the brain atrophy. The concreteness effect mentioned previously is also observed, and even more pronounced, in patients with SD.

However, in the literature there are also reports of **reverse concreteness effects**, where patients with SD process abstract words easier and faster than concrete words (e.g., *supplication* over *cabbage* (Warrington, 1975)). These rare cases challenge the scientifically established fact that concrete words are better understood than abstract words by healthy individuals, as well as by patients with SD. Some authors go insofar as to claim that this reverse effect is typical of SD. Moreover, these cases "contradict the neuroimaging findings showing that the left ATL is recruited more by abstract than concrete words, leading to the expectation that damage to that region should cause a greater impairment of abstract than concrete words" (Kemmerer, 2015:344).

Jefferies et al. (2009) claim that the reported (reverse imageability effects) RIE are atypical and thus not representative for SD. To test this hypothesis, they reviewed and tried to replicate the findings of the cases of RIE by testing 11 SD patients matched with 11 controls with ages between 56 and 65 on a synonym judgement test, with varied levels of frequency and imageability of the items. Specifically, the subjects were presented target words alongside two unrelated distracters (with the same levels of frequency and imageability) and simultaneous auditory and visual cues, and the patients had to point to the corresponding word. All patients achieved better results for more imageable and more frequent words, thus confirming the concreteness effect. For the frequency effect, the authors of this study offer two explanations: frequent words form stronger semantic representations than rare words, and they are acquired earlier in life and used more often, which makes them more resistant to general degradation of semantic knowledge (Jefferies et al., 2009:6). For the imageability effect, it is possible that imageable concepts have more detailed semantic representations (Jefferies et al., 2009:7). The results in this task contradict the view from RIE studies that the ATL plays an important role in sensory-visual processing, since the patients with lesions to this area underperformed in abstract words. Instead, the results point that both abstract and concrete concepts are represented in the ATL.

Jefferies et al. (2009) do not deny the reported reverse concreteness effects, but suggest that they rely on other factors. One possibility is atypical atrophy in the ATL (spared superior regions or spread to posterior areas of the inferior temporal cortex), which means that in this brain region there are several areas responsible for processing abstract and concrete words. This explanation is supported by the fact that most of the RIE reports are case studies, so investigations of one patient are conducted precisely because of his unusual symptoms. Another possible explanation is that the personal background of the patients (education, interests, experiences) can influence the frequency of certain words in a person's vocabulary, in that higher educated individuals are more familiar with more abstract and rare words. This was the case in most of the patients who displayed reverse concreteness effects (Hoffman/ Lambon Ralph, 2011:2109). Thus, Jefferies et al. (2009) conclude that the RIE are the result of reporting bias.

Their view is also supported by Hoffman/ Lambon Ralph (2011) who studied concreteness effects in seven SD patients, using several tests (synonym judgement test, description-to-noun matching task, description-to-verb matching task, verb similarity test, word-picture matching task, mischievous monkey test with pictures and with words).They found that the patients' overall comprehension was impaired for both abstract and concrete words, and slightly better for concrete words. However, the advantage of the concrete words was observed only in specific conditions: when the words in the concrete-abstract pairs were equally frequent, and when the concrete and abstract words had various imageability levels. These results reinforce the view of Jefferies et al. (2009) that reverse concreteness effects are atypical of SD.

Another explanation is that the concreteness effect arises if the tested words are not matched for familiarity, "leading to comparisons between more familiar (and therefore easier to process) concrete (e.g., *artichoke*) and less familiar, abstract (e.g., *heresy*) words" (Vigliocco, 2014:1767).

Another explanation for the reverse concreteness effects takes into consideration the role of emotion, as discussed in chapter 2.2. In the experiment of Vigliocco et al. (2014) the subject processed abstract words faster than concrete words. They conclude that from the three differentiating factors (concreteness, imageability, emotion) for abstract and concrete words, only emotion gives an advantage to abstract words. However, this study was conducted on healthy young adults and doesn't provide direct evidence individuals with cognitive decline.

In conclusion, the reverse concreteness effect is considered atypical and remains a controversial, but nevertheless interesting issue in SD.

5. Conclusion

The previous chapters illustrated the impact of aging on language, specifically on the semantic knowledge. The selected studies have shown both similarities and differences between healthy aging individuals and patients with SD.

A first **similarity** is the increasingly longer response time lexical decision tasks. The naming precision also deteriorates with age, respectively with the progression of the brain atrophy. Furthermore, the concreteness effect is observed in both groups, which means that both healthy aging individuals and SD patients generally process concrete words better and faster than abstract words. The cognitive decline affects first the retrieval or access of abstract concepts in the mental lexicon. Regarding speech production, in categorical naming task both groups have the greatest difficulty with *tools*, supposedly because it an inanimate and less familiar category. In contrast, they are able to name most items belonging to *body parts*, due to immediate experience or higher familiarity levels with them. The findings suggest that conceptual categories have different salience levels and are preserved differently in the mental lexicon, which makes them more or less resistant to cognitive decline.

Differences between the two groups are found in the naming abilities. Quantitatively, healthy aging individuals are able to produce more words than patients with SD in naming tasks for specific categories and for concepts beginning with a certain letter. This is due to the different degrees and nature of cognitive impairment. Qualitatively, in naming tasks healthy individuals are more accurate than SD patients. Typically, as SD progresses, patients start assigning more general and incorrect names to objects. This symptom does not occurs in healthy aging individuals, who despite responding slower, use the correct words. Differences are also category-specific, in that SD patients tend to have more difficulties with non-living than with living concepts. Neurologically, the progression of atrophy in SD patients correlates with the decrease of knowledge of noun objects.

Lastly, the literature review revealed some **controversial issues.** The first one is the reverse concreteness effect observed in some patients with SD. Though it has been shown that this pattern is not typical of SD, a satisfactory factual explanation is not yet available. The second issue is categorical specificity, which leaves the questions why semantic knowledge is more affected for certain categories, and whether conceptual knowledge is more precisely categorically represented in the brain.

Finally, an open question is whether concrete and abstract words are processed by different mechanisms in the brain. Should this be the case, the question arises whether concepts encoded in abstract words are represented by linguistic or non-linguistic factors (e.g. perception, motor) (Wang, 2010:1460). Following this line, the role of emotion in processing abstract concepts, in the context of embodiment theories, could provide further insights.

The above mentioned provide interesting points for further research in SD and healthy aging individuals.

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