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# Working Memory in Older Adults. Processing of Complex Syntactic Structures in Speakers of Rioplatense Spanish

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## Abstract

Fifty-four adults (27 over 60 and 27 young people) were exposed to complex sentences with temporal syntactic ambiguity in an online self-administered reading time task. Chronometric measures of reading times were taken and the degree of understanding of yes-no questions related to stimulus sentences was assessed. In addition, in order to assess whether older adults are sensitive to factors that may alter the demand for memory resources required for orational processing during reading, frequency of use, size and shape of words present in stimulus sentences were monitored, among other things. Older adults had lower working memory scores than young people in standardized tests conducted prior to the experiment. The hypothesis was that a decrease in overall working memory capabilities in older adults does not affect the level of syntactic processing. The results indicated that there were no significant group differences in reading times, although the older ones were less accurate in the yes-no questions. These results suggest that the memory resources needed to extract the orational meaning are preserved in the majors and that they were also sensitive to factors that reduce the processing cost. In the meantime, resources required to make use of these orational meanings, such as answering yes-no questions, would be affected by the ageing factor, but not exclusively. In sum, in line with current assumptions about the structure of working memory, the results point to the existence of highly specialized internal modules, one specific responsible for syntactic computation, and another linked to lexical-semantic information whose functioning becomes unstable over time.

***Keywords:*** *Working Memory; Processing; Older Adults; Syntactic Ambiguity; Modularity*

## Abbreviations

WM: Working Memory; SD: Standard Deviation; S: Sentence; ms: Milliseconds

## Introduction

While the study of psycholinguistic processes in relation to aging and its consequences on psychological mechanisms, such as working memory (WM), is a relatively new topic, some central publications [1-3] have established a set of fundamental ideas around the problem and allow to form a general picture that characterizes the language of the older adult, where among other things, there seems to be a decline in the processing of syntactically complex sentences presenting a significant increase in reading times or difficulties in their understanding.

WM can be conceived as a limited, short-lived memory capacity capable of simultaneously storing and manipulating information for the purpose of performing a particular task [4]. The tasks usually performed by humans, such as reflecting on a topic, solving problems or understanding what is said or read, are mediated by WM. The fact that the resources available to WM (generally referred to as processing resources) are limited has been widely used in the field of cognitive psychology to account for the behaviour of healthy subjects [5], with cognitive disorders [6] or elderly [7].

In the area of language, punctually, it has often been associated with a person having a higher amount of resources to better performance to understand sentences or texts than a person with low resources. This trend stems from the works of Just and Carpenter [5], who proposed the so-called unified capacity or resource theory, which has had a major influence on research aimed at examining language understanding in older adult subjects. According to this approach, orational processing depends on a single and limited source of memory resources that serves as a support mechanism for the execution of verbally mediated cognitive tasks. WM and processing capacity are narrowly interrelated notions, so that the greater or lesser difficulty of the linguistic operations required to process a given sentence results in an increase or decrease in memory resource demands. If the demands of the task exceed the available resources, the storage and compute functions are degraded, as shown by the processing times or error patterns associated with more demanding comprehension tasks. This theory assumes that the variability of people's performance in comprehension tasks depends on individual differences in WM's ability. The prediction is that a high WM capability, with more resources available for syntactic processing, will allow tosomeone to understand complex syntactic structures more quickly and with fewer errors, while an WM with few resources will be less efficient. In general, then, experimental syntactic processing tasks expect memory capacity effects and interactions that indicate that operational memory capacity modulates sentences processing. This model is supported by significant correlations between memory capacity measures and syntactic processing efficiency measures [7].

Alternatively, in line with the developments of generativist linguistics [8] investigating the existence of a psychological reality of syntactic structures, from a modular conception of syntactic processing [9,10] and on the basis of Baddeley's original work [11,12] that WM is divided into modules, Caplan and Waters [13] challenge the unified resource hypothesis. These authors propose that WM, in turn, has a subsystem made up of a set of memory resources specialized in real-time syntactic processing. The function of this (sub)syntactic module would be to interpret the linguistic signal of speech by extracting the meaning of sentences from the recognition and lexical access (detection of formal, phonological and semantic features), the establishment of syntactic relationships between lexical items and the assignment of thematic roles, among other aspects. This information that Caplan and Waters call interpretive would then be used in post-interpretative processes such as reasoning, problem solving or text understanding. Unlike the unified resource hypothesis, this hypothesis argues that WM´s overall performance does not predict the efficiency of syntactic processing, precisely because resources for this purpose are separated into a special module that would be preserved from the effects of age. Therefore, the loss of WM resources characteristic of older adults, should not affect orational processing. In general, according to this theory, experimental studies of online processing group effects with different WM capabilities are not expected. Nor are interactions between group and type of structure as the processing resources dedicated to the analysis of sentences and those dedicated to the retention of verbal material obtained from that analysis are functionally independent. This hypothesis has found support from empirical studies and the review of published papers related to healthy subjects and patients with WM impairment [13-15].

Although the hypotheses described do not share their concept of working memory, they do share the assumption that the resources required for sentence processing are limited and that the processing of complex syntactic structures, such as sentences containing syntactic ambiguities, requires greater use of such resources than simple structures.

Syntactic analysis processes are cognitive mechanisms that mediate between the recovery of lexical meaning (i.e. informally, the extraction of words from the mental lexicon) and the interpretation of the orational meaning (i.e. obtaining meaning when these words are

syntactically related within a sentence). These mechanisms are mostly unconscious, and operate automatically and often predictively, which can be misleading. Among the complex sentences that demand the greatest processing effort are ambiguous garden path sentences that present temporal syntactic ambiguity. The following is a common example in the literature about syntactic ambiguities in the English language: (i) While Anna dressed the baby spit up on the bed (Mientras Anna (se) vestía el bebé escupió en la cama).

When reading or listening (i), without a comma or pause after the verb dressed, the comprehension system momentarily assumes that it has found a structurally and semantically complete expression (While Anna dressed the baby), so it tends to end and interpret the sentence. But by perceiving the following part (spitup on the bed), he is forced to review his initial interpretation and to make a new one. These types of sentences are called garden path because they induce the reader to temporarily opt for the wrong path. The phrase marker generated by the parser system considers the term the baby as a direct object of the verb of the initial subordinate clause (While Anna dressed). The parser then carries out a reanalysis and assigns him the subject position of the main clause, since English is a language that requires express subject. The fact that an erroneous analysis is initially carried out (where the baby is considered a direct object) is a prediction made by virtually all theoretical models of syntactic processing, both serial-modular and also those of interactionist[1] type [16].

In Spanish, such structures also have a temporary ambiguity: (ii) As the cat swallowed the pigeon it fled for the text. (While the cat swallowed the pigeon fled through the roof.).

The analyses in this case can be (a) an initial phrase attached with a transitive subordinate verb (swallowed), where a cat swallows a pigeon and in the meantime someone or the cat itself flees through the roof. And, on the other hand, (b) with an initial attachment but with subordinate verb analyzed intransitively, where a cat swallows (something, not expressed in the statement) and, in the meantime, a pigeon flees through the ceiling.

As it is known, in Spanish, in the case of animated objects that function as internal complements of transitive verbs, these will be preceded by the preposition to e.g., el gato tragaba a la paloma. (the cat swallowed (to) the cat). In principle, in (ii), the absence of the a could alert the reader to avoid miscalculation. However, that does not happen, as readers seem to immediately associate the phrase in question with the verb preceding it as in English. This is because the syntactic processor performs an initial analysis according to a principle of cognitive economy that postulates that the first available analysis be adopted by attaching the incoming linguistic material to the current syntax (as serial-modular models predict), or because during processing it operates syntactic and extrasyntactic information that indicates that the subordinate verb swallow is frequently used as a transitive as interactive models predict.

The results of studies carried out in relation to English garden path sentences, in adults and older adults, agree to point out that there are group differences in the reading times of the complete sentence, of the critical word in which disambiguation occurs the matrix sentence verb spit up in (i) and in the accuracy of understanding, in favor of subjects with greater working memory capacity enduring, at least partially, the hypothesis of individual differences [22-25]. These results, however, do not override the hypothesis of divided re-

[1]Modular models hold that the linguistic processing system operates by informatively encapsulated subsystems (or modules). The syntactic module would be in charge of assigning the hierarchical structure of the components of each sentence that is heard or produced. The garden path model [17,18] maintains that the syntactic analysis subsystem accesses only syntactic information to elaborate the syntagmatic marker and that, in the face of a syntactic ambiguity, it selects one of them based on universal strategies. This would lead to the adoption of the first available analysis, which would be subsequently evaluated by a semantic component for a possible reanalysis. On the other hand, interactive models [19,20] work on the basis of rich lexical representations and the rapid use of multiple restrictions in the resolution of ambiguities. The processor can access syntactic and extra-syntactic information simultaneously. The processing is also carried out in parallel: faced with an ambiguous structure, the processor will have all the possible alternatives available and will decide which one is the most appropriate based on their frequency of use [21].

sources.

In the meantime, Spanish has hardly been explored in this regard. A published study that uses Spanish garden path sentences is that of Véliz and collaborators [26]. In this work, stimulus sentences of the type (ii) all refer to different topics or conceptual fields and, as for their structure, some incorporate passive periphrasical forms (e.g. Mientras el abogado escribia la apelacion fue rechazada por el tribunal. ( While the lawyer wrote the appeal was rejected by the court). Taken together, the experiment presents participants with a stimulus rich in their lexical diversity, varied in topics and with some complex aspects in syntax beyond the own complexity that supposes a temporary ambiguity.

This study aims to address the processing of ambiguous sentences similar to those of the Véliz and collaborators study by introducing some changes.

Certain lexicon organization models [27] assume the existence of a conceptual level, a kind of semantic network composed of interconnected nodes, where each node represents a certain concept that is linked to others through different relationships (e.g. semantic category, function). This semantic system is where the widely known effects of context and semantic facilitation take place. It has been observed that open-class words are recognized more quickly when they are in an appropriate context than when they are isolated (contextual effect) and also when preceded by other words related semantically or associatively (priming effect) [28,29]. On the other hand, it is known that, in general terms, the frequency with which the words of a language are used influences lexical access, i.e. frequent words are recognized (and produced) faster than the uncommon [30,31] and more-imaginable (concrete) words are better recognized than the abstract (less-imaginable) [32,33]. Another long-studied aspect is the influence of the shape of words in reading times. For example, there is evidence that complex words (with derivative or inflectional affixes) are more difficult to process than words with a single morpheme [34,35] and it has been pointed out that short words are often better processed than long ones, although this effect usually disappears at least in young adults [36,37].

Considering the previous, transforming a physical signal (graphemic or acoustic) into a semantic representation consistent with the speech level involves the use of WM resources to perform syntactic computation operations, but also requires other sub processes that take place on the phonic and semantic interfaces. The distinction between memory resources that the system parser uses for the realization of syntactic computations, on the one hand, and operations that are not stricto sensu syntactic, such as those related to lexical access, on the other, has been noted in studies based on current psycholinguistic models under the notion of processing cost [38-43].

It is proposed for the ongoing work to develop an experiment that, unlike other studies also carried out on the basis of temporary ambiguous sentences, controls factors such as those set out above, which may involve additional processing cost on the interfaces depending on the type of lexical items to be processed, for the purpose of assessing whether these factors affect syntactic processing. Moreover, it is proposed that stimulus sentences have a garden path effect and do not contain another type of complex structure (such as passive sentences) involving movement of constituents that may influence reading time measurements.

Based on the above, the reasoning guided by the experiment described below is as follows: assuming in older adults a natural decline in the overall capacity of WM against young adults [44] and on the assumption that such decline in WM resources due to natural aging does not reduce the specific capacity of interpretive processing [13], there are expected no significant differences between age groups in reading complex sentences.

## Aim of the Study

They aim as objectives, first of all, to assess whether age is a factor affecting the syntactic processing of complex garden path sentences versus unambiguous sentences based on reading time in the critical zone and the total reading time of each sentence; secondly, to assess

the degree of understanding of ambiguous and non-ambiguous syntactic structures and, in the case of ambiguous, whether the subjects opt indistinctly for any of the possible interpretations presented by the Spanish or whether there is any option that prevails over the other; Finally, assessing the extent to which the control of factors involving additional processing cost in the phonic and semantic interfaces may alter syntactic performance compared to results from other Spanish-language research.

## Materials and Methods

For the purpose of evaluating group differences in ambiguous sentence reading times, a moving-window word-by-word self-paced reading task is used. The ambiguous sentences used were of the type illustrated in (ii) since they are suitable for obtaining chronometric measures since, as noted above, the reader may initially consider that the phrase the pigeon is the direct object of the subordinate verb (swallow) by assigning thematic role of meta/theme, as the different processing models predict; then, the reader can pause momentarily in the verb of the matrix sentence fled to perform a reanalysis and assign a new structure, now with the phrase the pigeon as the subject of the matrix verb, or can continue with the initial interpretation until the end of the sentence without stopping[2]. Measuring reading times allows to analyze comprehension processes in real time, as longer processing times are assumed to involve a higher processing load for the WM. One of the assumptions that allow to interpret the measurements of reading time is that of immediacy, according to which the reader tries to understand each unity of the statement as soon as possible, without waiting for the end of the sentence. The second assumption, which is often referred to as the mind-eye, refers to the fact that the mind processes the unity in which the eye is fixed at that time, that is, there is no delay between the gaze and the process of understanding. This technique largely preserves the characteristics of normal reading, such as right left scrolling or word length information, but differs from normal reading in some respects, such as the inability to perform regressive movements. However, it is a technique that allows to obtain results very similar to those obtained with other techniques such as those that record eye movements [45]. Another measurement, in addition to the time in the area of the main verb, was the reading time of the full sentence. Finally, to assess the understanding of ambiguous structures, a first yes-no question was asked after each sentence and a second question (why?) which leads to an explanation in order to rule out contradictory answers. For example, after reading the sentence (ii) the participant read a question such as did the cat swallow the pigeon? If the answer was no and the participant gave an explanation of the type because the pigeon escapes, it was considered that there is no contradiction and that the answer is correct. If, on the other hand, the answer was yes; the pigeon escapes, or not; I believe/do not know, they were considered contradictory or dubious, and therefore incorrect.

In this regard, the successes were taken into account in order to recognize which of the possible readings the participants chose. So, considering (ii), following the question did the cat swallow the pigeon?, in case of answer yes (non-contradictory), it was considered that the interpreted structure was (a), i.e. an initial attachment with subordinate verb analyzed in transitive form, and in case of a no answer (non-contradictory), the option of reading was considered to be (b), i.e. an initial attached phrase with intransitive subordinate verb.

### Participants

The experiment was attended by 54 adult Spanish speakers residing in the city of Santa Fe (Argentina), 27 over 60 years and 27 young adults, all with at least full secondary studies and normal vision. The participating young adults were university students and administrative staff of local companies. Older adults were intellectually active individuals, administrative staff of public distributions of the city or students in senior study programs and had clinical history not associated with dementia or other signs of cognitive decline. All partici-

[2]It should be clarified that Spanish, being a pro-drop language, admits the elision of the express subject of the parent clause in (ii), with which the interpretation that while the cat swallowed a dove someone or the cat itself flees by the ceiling is possible.

| | Test | Older Adults | Young Adults | P-value |
|---|---|---|---|---|
| Age | | 68 (6.1) | 33 (14.4) | 0.0001 |
| WM | WAIS III, Digits Forward | 7.3 (1.8) | 9.0 (1.5) | 0.0001 |
| | WAIS III, Digits Behind | 4.5 (1.9) | 6.5 (1.9) | < 0.0001 |
| | Reading amplitude | 2.2 (0.6) | 2.7 (0.7) | 0.0001 |
| | WAIS III, Digit symbols | 8.9 (2.3) | 11.2 (2.2) | < 0.0001 |

***Table 1:*** *Means of assessed WM and SD capacities.*

pants performed the digit tests back and forth of the WAIS-III, Adult Intelligence Test [46], Reading Amplitude Test [47]. The measurements obtained are presented in table 1.

## Material

Three randomized lists of 36 sentences each, 6 introductions for familiarization, 10 with ambiguity of the exampled type in (ii), 10 unambiguously as in (iii), below, and 10 distractors of different orational structure and length were used as a stimulus. (iii) La paloma huyó por el techo mientras el gato tragaba' (The pigeon fled through the roof while the cat swallowed.

In the case of (iii), the subordinate is on the right and there is no ambiguity. Since the experiment aims to reduce the cost of processing in the extraction of information from interfaces, special attention was paid to the type of lexical items used in the elaboration of stimulus sentences (ambiguous and non-ambiguous). In order to minimize a possible lexical accessibility effect, the names of the nominal sintagmas that function as arguments for the verbal predicates of both the matrice and subordinate clauses (respectively the pigeon and the cat in example (ii)), all correspond to the set made up of animated beings (humans/animals), considered typical categories (i.e. common in colloquial speech of the area) and frequency normalized around mean and high values (between16.88 and 557.58, according to the Reference Corpus of the Current Spanish). As for the shape of the names used, it was meant that they were all between two and three syllables in size. The verbs used all correspond to simple shapes. Those verbs corresponding to the subordinate clauses (e.g., tragaba), are characterized by being transitive and being able to express or not the internal argument. The matrix verbs (e.g. huyó) are all predicates whose argumental structure is saturated with a single argument.

List of stimuli used in the experiment

| |
|---|
| 1a- Mientras el perro (44,48) lamía la leche (73,67) caía del vaso (39,09).<br>( While the dog licked the milk fell from the glass.)<br>1b- La leche caía del vaso mientras el perro lamía.<br>(The milk fell from the glass while the dog licked.). |
| 2a- Mientras el hombre (525,38) barría la casa (557,58) quedó a oscuras (17,31).<br>(While the man swept the house was left in the dark.)<br>2b- TLa casa quedó a oscuras mientras el hombre barría.<br>(The house was left in the dark while the man swept.) |
| 3a- Mientras el patrón (26,29) esperaba la lluvia (49,16) cayó tras la montaña (37,54).<br>(While the skipper waited the rain fell behind the mountain.)<br>3b- La lluvia cayó tras la montaña mientras el patrón esperaba.<br>(The rain fell behind the mountain while the skipper waited.) |
| 4a- Mientras la mujer (405,98) compraba el pollo (19,61) corría por el patio (38,9).<br>(While the woman bought the chicken ran around the patio.)<br>4b- El pollo corría por el patio mientras la mujer compraba.<br>(The chicken ran around the patio while the woman bought.) |
| 5a- Mientras el perro (44,48) mordía el cerdo (16,88) escapó por la ventana (59,36).<br>(While the dog bit the pig escaped through the window.)<br>5b- El cerdo escapó por la ventana mientras el perro mordía.<br>(The pig escaped through the window while the dog bit.) |
| 6a- Mientras la niña (72,01) cocinaba los huevos (36,98) cayeron al suelo (134,8).<br>(While the girl cooked the eggs fell to the ground.)<br>6b- Los huevos cayeron al suelo mientras la niña cocinaba.<br>(The eggs fell to the ground while the girl cooked.) |
| 7a- Mientras el joven (177,13) tomaba el vino (114,65) desapareció de la mesa (141,3).<br>(While the young man drank the wine disappeared from the table.)<br>7b- El vino desapareció de la mesa mientras el joven tomaba.<br>(The wine disappeared from the table while the young man drank. |
| 8a- Mientras los vecinos (73,23) atacaban las aves (21,48) volaron sobre los árboles (48,36).<br>(While the neighbors attacked the birds flew over the trees.)<br>8b- Las aves volaron sobre los árboles mientras los vecinos atacaban.<br>The birds flew over trees while the neighbors attacked.) |
| 9a- Mientras la mujer (405,98) planchaba la camisa (26,56) desapareció por la ventana (59,36).<br>(While the woman was ironing the shirt disappeared through the window.)<br>9b- La camisa desapareció por la ventana mientras la mujer planchaba.<br>(The shirt disappeared through the window while the woman ironed.) |
| 10a- Mientras el gato (25,66) tragaba la paloma (18,81) huyó por el techo (32,07).<br>(While the cat swallowed the pigeon fled through the roof.)<br>10b- La paloma huyó por el techo mientras el gato tragaba.<br>(The pigeon fled through the roof while the cat swallowed) |

### Procedure

The test is applied in a secluded and quiet place. The participant is proposed a game in which people and animals carry out certain activities on a farm. The game consists of reading sentences as quickly as possible and answering questions for yes or no for each sentence, with a brief justification (i.e. question: why?). At the start of the task, the participant sees on the computer screen (Samsung Np300e5a laptop was used) numerals and spaces (e.g., ##### ## ###### ##### ### #####).The numerals series correspond to words and spaces with the separation between words. As the participant presses a key, successive words are unmasked and those already read are masked. The subject may see one word at a time but has information on the length of the words (by the spatial arrangement of numerals and spaces), which can be captured by peripheral vision. The reading rhythm is therefore the one printed by the reader. The times used to press each key are recorded by a program (DMDX Automode version 5.0[3]software was used) so that on this basis times can be calculated in both critical and total reading areas of each sentence. In addition, the understanding answers that participants give to each question-yes-no question, as well as the times required by the reader to answer each question, are also recorded for further analysis. Questions of type why? assess possible contradictions were recorded separately on digital media and were not taken into account for time calculations.

The implementation of the experiment had an approximate average duration per participant of 25 minutes; in some cases, an intermediate pause was made at the request of the participant.

## Results and Discussion

Reading times (in the word critical and full sentence) in milliseconds (ms) and the number of hits (in answers to yes-no comprehension questions) were taken as dependent variables. Based on the data obtained, a series of ANOVAs(design 2 X 2) was applied, where the independent variables were age (older adults and young people) as a group factor and the type of sentence (ambiguous or non-ambiguous) as a repeated measure. Outliers were discarded, per word, using the Z-3 value. The InfoStat statistical package (2008) [49] was used for the analysis.

For its part, to check which of the possible readings readers choose in ambiguous sentences, it discriminated between hits according to options (a) and (b), and the sum of hits by option was subjected to a binomial test.

## Results

### Times in the critical word: the verb of the matrix sentence

A main effect Sentence Type was obtained $F(1.16) = 12.1$ $p < .003$, with longer times in ambiguous structures. There was no main effect Age $F(1.16) = 0.894$ $p < .35$, no interaction effect Age*Sentence Type $F(1.16) = 3.42$ $p < .08$. Table 2 presents the time averages recorded in the critical zone.

These results suggest that ambiguous sentences are more difficult to process than non-ambiguous ones for both age groups. However, they are no more difficult for older adults than for young people, as there was no group effect or interaction between variables.

[3]DMDX, developed by Ken and Jonathan Forster at Monash and Arizona Universities (http://www.u.arizona.edu/~jforster/dmdx.htm).

| | Main verb | | | |
|---|---|---|---|---|
| | S. ambiguous | | S. no-ambiguous | |
| | Media | SD | Media | SD |
| Seniors | 719 | 384 | 598 | 340 |
| Young Adults | 563 | 41 | 526 | 74 |

***Table 2:*** *Average reading times (ms) in the critical word.*

## Reading times for complete sentences

There was a main effect Sentence Type $F(1.16) = 5.97$ $p < .03$, with higher total reading times in the case of ambiguous sentences. Nor in this case was the main effect of group, Age $F(1.16) = 1.68$ $p < .21$, nor was there interaction Age* Sentence Type $F(1.16) = 2.25$ $p < .15$.

| | Full Sentence | | | |
|---|---|---|---|---|
| | S. ambiguous | | S. no-ambiguous | |
| | Media | SD | Media | SD |
| Seniors | 7033 | 3121 | 6443 | 2785 |
| Young Adults | 5530 | 430 | 5389 | 488 |

***Table 3:*** *Average time (ms) of reading complete sentence.*

The results of the variance analysis suggest that there are no significant differences in timed reading times between older adults and young adults. This is confirmed by the no interaction between the group variable and the structure type. The factor that does influence and alter reading time is structural, i.e. when there is more than one reading possibility, there is greater demand for processing in both groups.

## Hits in answers to comprehension questions

Two main effects were obtained, Age $F(1.16) = 12.3$ $p < .003$, with more hits in the youth group and Sentence Type $F(1.16) = 52.0$ $p < .000001$, with more hits in non-ambiguous sentences. There was no interaction effect Age*Sentence Type $F(1.16) = 1.92$ $p < .18$.

| | Correct answers | | | |
|---|---|---|---|---|
| | S. ambiguous (No. 10) | | S. no-ambiguous (No. 10) | |
| | Media | SD | Media | SD |
| Seniors | 5 | 1,6 | 8 | 1,3 |
| Young Adults | 7 | 1,5 | 9 | 0,9 |

***Table 4:*** *Means of correct yes-no questions.*

It follows from statistical analysis that older adults have significantly more difficulty understanding structures both ambiguous and non-ambiguous than young people. Ambiguous clauses are more difficult to understand than non-ambiguous ones for both age groups. The fact that there is no interaction between variables prevents the claim that advanced age is necessarily the cause of the greatest number of years of understanding.

### Times required to answer yes/no questions

A main group effect was found, Age (1.16) = 12.8 p < .002, with longer time averages in older adults. There was no effect Sentence Type F(1.16) = 0.644 p < .43, no interaction Age*Sentence Type F(1.16) = 0.030 p < .86.

| | Response times | | | |
|---|---|---|---|---|
| | S. ambiguous | | S. no-ambiguous | |
| | Media | SD | Media | SD |
| Seniors | 4135 | 521 | 4233 | 938 |
| Young Adults | 2794 | 898 | 2947 | 950 |

***Table 5:*** *Averages of response times (ms).*

The results in table 5 suggest that older adults significantly take longer to respond than young people. The type of sentence does not appear to be a factor influencing response time, as both groups answer each other sentences in similar times.

### The structure that selects the processing system for ambiguous sentences

The analysis carried out on the basis of Table 4 suggests that young adults are generally more successful than older adults in ambiguous sentences. However, nothing is expressed there as to which of the reading options is selected by the participants: (a) or (b). In order to have an approximation in this regard, the sum of the successes of ambiguous sentences per age group according to the type of analysis ((a) or (b)) was considered and those values were subjected to a binomial test. In young adults, the correct answers following the analysis (b) are on chance (184 out of 189; p-0.0001), i.e. 97.4% of the time the structure was selected (b); equally in older adults (120 out of 135; p-0.0001) it was interpreted according to structure (b) in 88.9% of cases. These results suggest that there is a preference for structure that assumes that the subordinate-verb in (ii) functions as an intransitive in both age groups.

## Discussion

The main objective of this study was to verify whether adults over 60 years of age, speakers of the rioplatense Spanish, can process complex sentences, such as the temporary ambiguous of the type of (ii), similar to how younger adults do, based on the hypothesis that while older adults have a natural decline in their verbal abilities of WM, there are special resources for syntactic processing that are not affected by the age factor [13]. To check the degree of difficulty in syntactic processing, a self-monitored reading online task was used and assumed that higher reading times in the critical zone (main verb of the matrix clause) and full sentence involve the use of more WM resources. The results of the implementation of statistical tests indicated that there were no significant group differences in reading times in both critical and full sentences, in line with results from current studies [50,51]. In addition, and more importantly, there were no effects of interaction between group and sentence type. As Caplan and Waters point out, an interaction would be linking these variables causally, meaning age would be a factor that would be influencing and would cause difficulties in sentence processing, which, at least in this experiment, did not happen. On the other hand, it was observed that older adults do have comprehension difficulties, as they responded significantly more mistakes to the yes/no questions asked after each sentence read. In addition, the significantly longer time they spent to answer such questions, suggesting that the difference between groups lies not in the reading times of the stimuli presented, but in aspects of post-interpretational processing, i.e. off-line processes involving other types of resources. However, the cause of this poor performance in understanding in older adults should not be necessary or entirely attributed to age, to the extent that there was also no interaction effect in this case. On the other hand, the type of ambiguous Spanish sentence used in the experiment allows more than one reading and it was established that the preferential option (the one corresponding to correctly answered questions) is one in which the subordinate verb is considered to be intransitive, resembling the behavior of both age groups.

Similar results were obtained in the study on ambiguous garden path sentences of Spanish carried out by Véliz and collaborators. In this research, there were also no effects of group-type interaction of sentence, either in reading times in the critical area or of full sentence, but, unlike the present study, there was a main effect of age on reading times, with higher values in older adults. A main effect of age implies that older adults were less efficient (i.e., delayed longer) in syntactically processing ambiguous and non-ambiguous stimulus sentences. However, the authors note, this is not directly attributable to the decreased WM of older adults, given precisely the absence of Age-Type of Sentence interaction.

Thus, arises the question of what makes in one experiment older adults more efficient than in the other in their syntactic performance in the face of ambiguous garden path sentences. In that sense, assuming that sentence parsing involves a processing cost, i.e., the use of a greater or lesser amount of memory resources depending on the complexity of the orational analysis, and that it includes factors that are not specifically syntactic in addition to the cost of syntactic computation, the response may lie in controlling those factors that add cost of processing in the phonic and semantic interfaces. But how do these factors operate?

Online processing models that refer to generative linguistics to explain the understanding of utterances [39,40], assume that the acoustic signal of speech is segmented and the lexemas (the phonological forms of lexical items) are recognized, from which lexical access occurs, to the extent that a search is initiated in the mental lexicon of the lemas (containing syntactic-semantic information) corresponding to the segmented lexemas. That is, there is formal (syntactic) information that is retrieved from the mental lexicon during the online processing in the comprehension (and production) of sentences and the computational system acts on the formal features contained in the recognized lexical items, which in turn allows the generation of the corresponding hierarchical structures. The derivation (informally, the generation of the mental representation of a sentence) proceeds in this way in phases, that is, as soon as there is a syntactically ordered piece of material that can be interpreted semantically, the result of the syntactic computation is transferred to the interface levels, i.e. it becomes accessible to processing systems [52].

Important here is that lexical access is a precondition for the assembly of lexical pieces, and it is crucial, because it is a moment, during processing, permeable to interference factors such as the frequency of use of items in the speech of a community, effects of priming with the previous discourse, or to the morphological form of the segmented items, among other aspects. Thus, the initial analysis of ambiguous structures such as (ii) is closed once the thematic role is assigned to the internal argument (la paloma (the pigeon)) of the subordinate verb (tragar (swallow)). From this perspective, the computational processing of the initial segment is carried out because the parsing system is automatic and is activated by the presence (of formal features) of the selected lexical items of the mental lexicon. However, the search for lemas (concepts) within the mental lexicon may be more vulnerable in older adults due to possible interference in lexical access related to the factors already mentioned. In other words, the interpretative resources proposed by Caplan and Waters appear to be operational in older adults as well as in young people because syntactic computing takes place 'despite everything', in extremely short times, although there may be some interference from pre-syntactic factors that produce group effects in the case of Véliz and collaborators. Such factors can also act at a later time of processing, when the subordinate sentence is retrieved from memory for reanalysis. At the moment when a nominal phrase is thus retained (e.g. the cat inside While the cat swallowed...), may interfere with factors that hinder comprehension, as the operating memory has little holding capacity and a competition could be established with other previously activated structures.

There is evidence that cognitive aging brings a number of difficulties in handling irrelevant information in WM [53,54]. Subjects over 60 years old would have defective inhibitory mechanisms at the attention level of WM, which would cause more information to be activated against certain verbal stimuli than the relevant one, resulting in such interference, in the sense of erroneous associations and the consequent misconception of concepts [55]. Another type of interference that might be operating during access to the lexicon is that of new information acting on the existing one, causing its forgetfulness. While this effect, called retroactive interference, is common in young

and old, it becomes more evident in the second case [56].

For its part, it should be remembered that the experiment of this study was proposed to the participants as a discursive situation (a game) in which from the beginning it is proposed that there will be characters who carry out certain actions within a defined space. This contextual framework could help to pre-activate information that would facilitate its processing.

When it comes to understanding ambiguous and non-ambiguous stimulus sentences, the error rate is significantly higher in older adults. Following the reasoning above, it is possible that having to process the yes-no questions and then having to reactivate the propositional meaning of stimulus sentences, implies an excessive cost which leads to errors related to the use of post-interpretational resources. However, there were no group-type interaction effects of sentences, either on the number of hits or for answer times to yes-no questions, so that poor performance in understanding by the elderly cannot be entirely attributable to aging as other factors may be intervening negatively.

It follows that, in the context of this experiment, there are probably such specific resources for interpretative processing referred to in the hypothesis of divided resources and which are not committed by the effect of aging. In addition, unlike the Véliz and collaborators experiment, it is observed that older adults do not have a significant difference in the efficiency of processing ambiguous and non-ambiguous sentences in relation to young people, which can be attributed to the sensitivity of the elderly to issues of accessibility and/or lexical organization. In other words, 'if the sentences used contain frequent words, not very long, with simple morphology and that have a certain degree of relationship with the general topic of the experiment, the elders read just as fast as the young. This suggests that, at least in part due to aging, changes in verbal memory arise that seem to selectively affect a set of resources linked to the lexical-semantic system leaving intact the resources of the syntactic computing system.

Such a dissociation has been noted for subjects with Williams Syndrome, although there are currently conflicting positions found in this regard [57]. Clahsen and Almazan [58] found that the performance of four English-speaking children with Williams Syndrome in the face of reversible passive sentences reflective anaphores and regular verbal forms in the past tense was unaffected, while they struggled with irregular forms. In addition, they noted that compared to children diagnosed with Specific Language Impairment, the pattern was given inversely, a deficitary syntax, and an associative memory of preserved irregular verbs. The conclusion was that within the language system the grammatical rules and lexical-semantic organization correspond to two different modules. In the same vein are the results obtained in a series of studies commented by Bellugi and collaborators [59], which emphasize the good performance of adolescents and adults with Williams Syndrome related to complex syntactic structures, but with deficit or unusual lexical-semantic abilities. In particular, a broad, atypical and sophisticated vocabulary has been observed, with the use of very low-frequency words, sometimes inadequate but within the correct semantic field (e.g. saying 'I evacuated a glass of water' instead of 'I drank a glass with water') as well as an abnormal semantic processing in tending to choose the less frequent meaning of homonymous words [60]. On the other hand, in case studies in the field of Developmental Amnesia, reading difficulties have been observed, with a deteriorated lexical-semantic system, high levels of homophone confusion, but intact phonological reading [61]. Finally, it has been pointed out that the lexicon and grammar systems not only depend on different brain circuits and areas (temporal and frontal-subcortical) [62], but are also altered by different brain pathologies (Wernicke and Broca aphasia), and are mediated by different types of learning (declarative and procedural) [63]. What is relevant about these studies in relation to this work is that they also pose a differentiation between subsystems within the language system, and that there are renewed attempts to locate these systems in the biological substrate of the brain.

In the case of older adults, a system dedicated exclusively to syntactic computing appears to be preserved while the structure and/or

dynamics of activation of the lexicon seems to become unstable with age. The latter suggests that internal submodules could be distinguished within the interpretative resources identified by Caplan and Waters.

## Conclusion

Based on the questions posed at the beginning of whether age is a factor affecting the syntactic processing of complex sentences with temporal ambiguity versus unambiguous sentences, considering the reading time in the critical zone and the total reading time of each sentence, the answer is no. This favors the hypothesis of divided resources and therefore the idea of a modular structure of working memory. Secondly, as to the degree of understanding of sentences, the results are not so clear, as there was greater accuracy in the responses of the younger ones and that supports the hypothesis that a deficitary WM affects the level of orational understanding, especially when the syntax is very complex. However, the variance analysis did not indicate interaction between variables, suggesting that advanced age cannot be considered as a single causal factor for low performance and that other factors may be affecting so-called post-interpretative processes. Finally, comparing the results with another similar study of Spanish, it is observed that older adults are sensitive to lexical factors that affect the amount of resources needed to extract orational information from the phonic and semantic interfaces. In particular, the lexical-semantic system, whose operation is highly automated and interrelated to the syntactic computing system, declines with age, although other factors independent of aging should not be ruled out.

## Limitations of the Study

A limitation of this study focuses on the small amount of stimuli presented to participants. This is because during the piloting stage the older adults pointed out that the experiment seemed too extensive to them. Moreover, the results were not considered individually, which would allow for the evaluation of a possible correlation between WM and reading times. Finally, in order to compare the performance of subjects within the same experiment, you can expand the number of participants, maintain the number of stimuli, and add as a separate variable the cost of processing on the interfaces.

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