Cognition, Brain, Behavior. An Interdisciplinary Journal Copyright © 2009 Romanian Association for Cognitive Science. All rights reserved. ISSN: 1224-8398 Volume XIII, No. 2 (June), 91-119



WORKING MEMORY CAPACITY IN LEXICAL DISAMBIGUATION: AN AGE DIFFERENCE APPROACH

Róbert BALÁZSI^{*}, Éva KÁLLAY, Oana GHIMBULUŢ

Department of Psychology, Babeş-Bolyai University, Cluj-Napoca, Romania

ABSTRACT

The present paper, including two experimental studies, explored whether the underlying mechanism of working memory (WM) supporting lexical disambiguation is a general (activation or inhibition) or a specific cognitive resource (involved only in interpretive processes). Regarding general WM resources, we also investigated whether the implied cognitive resources are activating or inhibitory in nature. The aim of the present paper is to test the predictions of the three above mentioned hypotheses in the context of age differences using an experimental paradigm proposed by Miyake, Carpenter, and Just (1994). The obtained results excluded the possibility that there are specific WM resources specifically allocated to lexical disambiguation (considered as an interpretive process). The obtained data confirm the implication of a general activation mechanism, and explain the observed age differences in lexical disambiguation due to the decline of the activation mechanism. However, the nature of this mechanism is still not clear; it can be a general activating attention mechanism of the central executive or a mechanism of short term maintenance (such as phonological buffer processes).

KEYWORDS: lexical disambiguation, working memory, cognitive inhibition, aging.

^{*} Corresponding author: E-mail: robertbalazsi@psychology.ro

INTRODUCTION

Literature distinguishes between two types of approaches to written language comprehension: comprehension *as the process of meaning construction* and comprehension as the process of *using constructed meaning* (Clark & Clark, 1977). The psycholinguistic mechanisms involved in meaning construction are called interpretive, and usually assessed by on-line measures of language comprehension (for example, eye-tracking techniques or reaction time in semantic priming tasks). Processes involved in using the output of language comprehension are named post-interpretive, and are measured with off-line tasks (for example, correct answers to questions regarding the explicit/implicit contents of a text or recalling the logical units of a paragraph) (Rodd, Gaskell, & Marslen-Wilson, 2002).

The concept of lexical access defines the processes that enable the retrieval of a word form from the lexicon on the basis of the available perceptual information (Monsell, Doyle, & Haggard, 1989). During the lexical access the word form and the phonological, semantic, syntactic and thematic information associated to its representation in the mental lexicon are simultaneously activated (Murray & Forster, 2004). According to this approach, lexical access is considered to be a process that contributes to the construction of meaning, thus in terms of the above distinction it is an interpretive psycholinguistic process.

In all languages there are words that have two or more meanings and one spelling and pronunciation named homograph (for example, *boxer*), which explains why written (and more often oral) language is an ambiguous stimulus. Typically one meaning of such a word (the dominant) has a higher frequency in language usage than the other (the subordinate) (Binder & Morris, 1995). In these cases, the construction of meaning involves, beyond the lexical access, a lexical disambiguation phase or in terms of Zwitserlood's (1989) approach, a lexical selection phase. During this second phase, the meaning that fits the actual semantic context is retained.

Without exception, all the current models of meaning disambiguation emphasize the importance of the semantic and syntactic context in this process. What distinguishes them is the moment when the contextual information exerts its effect on meaning selection. Based on this criterion we distinguish two types of models of lexical access: the context-dependent lexical access and the contextindependent access (Murray & Forster, 2004).

The context-independent access model (Conrad, 1974) assumes a strictly bottom up process, which result in the activation of all meanings of an ambiguous word. In the second phase, based on the available semantic, syntactic context a choice is made and one of the activated meanings is selected (Onifer & Swinney, 1981). The context-dependent access model (Swinney, 1979) allocates a more important role to contextual information. Accordingly, the available semantic information intervenes in the early phases of lexical access, thus participating in the activation of a single meaning, the one that is compatible with the present context. Both models imply the integration of all available linguistic information, the activated meanings of the ambiguous word and the semantic or syntactic context. It seems plausible that such integrative processes take place within the working memory system (WM) (Gunter, Wagner, & Friederici, 2003).

The studies that try to verify the implication of working memory in the process of lexical disambiguation use two types of experimental tasks: i) sentences in which the disambiguating context precedes the ambiguous word. The comprehension of such a sentence requires the maintaining of the contextual information activated, until the ambiguous word is met; and, ii) sentences in which the ambiguous word is preceded by a neutral context, and the disambiguating cue comes after the ambiguous word. A correct interpretation in this case supposes maintaining the activated meaning of the homograph in working memory until the disambiguating cue is met.

Regarding the first type of tasks it was found that sentences containing ambiguous words are processed more slowly than those containing non-ambiguous words, this being named lexical ambiguity effect (Binder & Morris, 1995; Dopkins, Morris, & Rayner, 1992; Klepousniotou, 2002). This effect is however not the same for all participants, those with reduced WM capacity (highlighted by SPAN measures) are more affected than those with high WM capacity (Swaab, Brown, & Hagoort, 2003).

Clinical studies have repeatedly confirmed the role of WM in maintaining contextual information in order to disambiguate a phrase. Schizophrenia, a clinical disorder which is associated with a significant decline of WM capacity (highlighted by classical measures) is frequently associated with erroneous interpretation of ambiguous words in context. The number of committed errors progressively increases as the distance between the semantic context and the ambiguous word is increasing (Titone, Levy, & Holzman, 2000). Similar results occur in elderly people who have deficits in efficient use of contextual elements due to a decline in the WM capacity (Dagerman, MacDonald, & Harm, 2006). In both cases there is a reduction of the WM capacity that is associated with a failure in lexical disambiguation.

Such a decline in the capacity of WM in elderly people also explains age differences in erroneous language processing: establishing the referential relations of a pronoun (Morrow, Altieri, & Leirer, 1992), and the use of a degraded output (Speranza, Daneman, & Schneider, 2000). The age differences disappear when the speed of processing is individually adjusted for each subject (Hopkins, Kellas, & Paul, 1995). It was also demonstrated that one can not establish a clear dichotomy between the use and non-use of linguistic context, to differentiate performances of young and elderly subjects. Rather, there is continuity, elderly also using contextual information but to a lesser extent than young subjects do (Federmeier, McLennan, De Ochoa, & Kutas, 2002).

Regarding the second type of tasks, the absence of a semantic context will activate all of the meanings of the ambiguous word (Rodd, Gaskell, & Marslen-

Wilson, 2002; Klepousniotou, 2002). There are three hypothetical models that try to explain the mechanisms involved in the disambiguation of such sentences, but the numbers of systematic inquires that try to verify such processes are much more reduced.

Just and Carpenter (1992) considers that the interpretive processes (such as lexical access or syntactic integration) and the post-interpretive processes (for example, inferences based on a text) are supported by a single WM capacity assessed by classical SPAN tasks. This hypothesis claims that the involvement of WM in reading language input efficiently relates to "activation" processes. Individual differences in working memory are explained by differences in the efficiency of activation mechanisms available to the cognitive system (Madden & Zwaan, 2006). An individual with a high WM capacity is assumed to activate and keep activated both meanings of an ambiguous word (the dominant and the subordinate), whereas a person with low WM capacity maintains only one meaning activated (usually the dominant one) (Cohen, Barch, Carter, & Servan-Schreiber, 1999; Bagner, Melinder, & Barch, 2003). The differences will be greater if the presentation of the cue is delayed, because in this case the person must maintain both meanings activated for a longer period of time.

To test this hypothesis Miyake, Carpenter, and Just (1994) presented to participants a series of ambiguous sentences in which the ambiguous word was preceded by a neutral context and followed by a disambiguating cue (e.g., Since *Ken really liked the* boxer, *he took a bus to the nearest pet store to by the animal*). They manipulated: the distance between the ambiguous word and the disambiguating cue (short vs. long) and disparity between the frequencies of usage of the homograph's two interpretations (dominant vs. subordinate), using WM capacity as a moderator variable. The results have shown that the efficiency of the integration of the disambiguation cue depends on the activation available for the cognitive system. A person with high WM capacity integrates the disambiguating cue more faster than those with low capacity, regardless of which interpretation of the homograph was correct (dominant vs. subordinate), or the distance between homograph and the disambiguating cue (short vs. long). Subjects with high memory capacity can process the phrase even if they had to maintain both meanings activated over longer periods of time, but subjects with reduced capacity, because of the lack of resources, "give up" one meaning (usually the subordinate one) (Murray & Forster, 2004). Keeping both meanings activated reduces the time necessary to integrate the disambiguation cue regardless if it matches the dominant or the subordinate meaning. As a consequence of loosing some information from WM (usually the subordinate meaning) supplementary strategic search in long term memory is needed in order to retrieve the lost information (subordinate bias effect). This mechanism explains why subjects with reduced WM capacity need more time to perform the same task (Cantor & Engle, 1993).

In opposition to the explanatory model proposed by Just and Carpenter (1992), Waters and Caplan (1996) consider that WM, measured by SPAN task

assesses a general cognitive resource, which serves only post-interpretive processes (Rochon, Waters, & Caplan, 1994). The explanation offered by Waters and Caplan (1996) is based on the distinction between interpretive and post-interpretive linguistic processes, lexical access being included in the first category. Considerable amount of behavioural and neuropsychological evidence sustains the existence of separate working-memory systems for verbal and nonverbal tasks (Miyake & Shah, 1999). The model presented by Waters and Caplan (1996) tries to further extend the dissociation of WM resources, subdividing the verbal working memory resource system. WM capacity assessed by SPAN tasks represents a general capacity allocated only to post-interpretive processes, and it is independent of those WM resources which sustain interpretive processes, as would be the lexical access.

Several studies have found that low-span or older individuals with limitations in WM capacity do not have increased difficulties in: processing syntactically complex sentences, such as garden path sentences (Waters & Caplan, 1997; Waters, Rochon, & Caplan, 1998); processing syntactically more complex sentences under concurrent memory load conditions (Waters, Caplan, & Rochon, 1995). They also found that the WM allocated to on-line processes was not affected in elderly who suffer from Alzheimer or Parkinson disease (Waters & Caplan, 1997; Waters & Caplan, 2005).

The last hypothesis, formulated by Gunter and Friederici (1999), assume that the most important mechanism implied in disambiguating ambiguous sentences is cognitive inhibition, and not a general activation process (Gernsbacher & Faust, 1991); Shivde & Anderson, 2001). According to the authors, reading an ambiguous word activates all the meanings regardless of the presence or absence of a previously disambiguating context (Simpson & Burgess, 1985; Rodd, Gaskell, & Marslen-Wilson, 2002; Sereno, O'Donnell, & Rayner, 2006). The existence of a semantic context, does not prevent the activation of both meanings, but reduces the level of activation of that one which is incongruent with semantic context. As a consequence, its activation will rapidly (approximately after 200 ms after reading the ambiguous word) fall below the threshold (Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982). This reduction in the level of activation of the incongruent meaning is realized by an active suppression mechanism, guided by the information within the previous semantic context (Frattali, Hanna, McGinty, Gerber, Wesley, Grafman, et al., 2006; Gernsbacher, Keysar, Robertson, & Werner, 2001; Gunter, Wagner, & Friederici, 2003).

This hypothesis was tested in the context of syntactic ambiguity, registering electrical brain activity of low- and high-WM span individuals (Vos & Friederici, 2003; Vos, Gunter, Schriefers, & Friederici, 2001). The results suggest that high-span individuals activate only one syntactic structure, regardless the presence of the preceding semantic context, or of the intersentential syntactic context (Vos & Friederici, 2003). Low-span individuals seem to activate and maintain both syntactic structures, which cause interference in the disambiguating

phase of the sentence. The same mechanism seems to explain the process of disambiguating a homograph, presented in the middle of a sentence (Hagoort & Brown, 1994). Immediately after reading the ambiguous word the parser integrates the dominant meaning, because it has a higher rest of activation. If this meaning does not match the disambiguating cue, which comes after, the subordinate meaning will be chosen as the proper solution.

Reduced efficiency of suppression characterizes subjects with reading difficulties (De Beni & Palladino, 2000). Regarding this population, research has evinced significant correlations between understanding of phrases, understanding of comics (Gernsbacher, Varner, & Faust, 1990), and understanding a text, and the ability to suppress irrelevant meanings of a specific homograph (Gernsbacher & Faust, 1991).

The aim of present paper is to test the predictions of the three hypotheses mentioned above in the context of age differences, using the experimental paradigm proposed by Miyake et al. (1994). Taken into consideration the cognitive particularities of the two age categories (young and old participants) we will try to differentiate between the hypotheses regarding the implication of a general resource (inhibition or activation) vs. the one that emphasize the importance of specific WM resources, allocated only to interpretive linguistic processes. The same design will offer the possibility to validate the prediction of one of the two models which highlights the importance of general mechanisms in disambiguating homograph, inhibition vs. activation mechanisms.

Experiment 1

The reading of an ambiguous word will activate all the possible meanings associated with it (Duffy, Kamba, & Rayner, 2001; Murray & Forster, 2004).

In the absence of a context which can enable the immediate decision about which interpretation is correct, all the possible meanings should be maintained activated. According to the activation model (Just & Carpenter, 1992) keeping the possible meanings of a word activated will reduce the time needed for the integration of the disambiguating cue; regardless the sense of disambiguation (dominant or subordinate meaning). If the general mechanisms of WM responsible for maintaining information activated are also involved in lexical disambiguation then: i) processing an ambiguous word in a neutral context will yield no differences between young and elderly subjects for phrases where the homograph is disambiguated towards the dominant meaning. There will be no differences because the dominant meaning having a high level of activation will compensate for the lowered activation capacity of elderly people; ii) the activation level of the subordinate meaning is much lower than for the dominant one, therefore, it is likely that the elders lacking sufficient activation capacity, will not have immediate access to the subordinate meaning when they attain the disambiguating cue. The age differences will be more evident in biased phrases, where the dominant and

subordinate meanings of the homograph are very asymmetric, because of their relative frequency in quotidian usage, as opposed to equibiased phrases.

The alternative explanation, based on the general inhibition model, suggests that activating and maintaining both meanings activated creates interference in the WM and will cause difficulties in integrating the disambiguating cue (Gunter, Wagner, & Friederici, 2003). According to this model, the decision upon which meaning will be selected is taken immediately after reading the homograph, and is based on existing information. In a neutral context, the only information available is represented by the differences between the degrees of association of the homograph to its various meanings. According to the model, young people are characterized by more effective inhibitory mechanisms compared to the elderly. Therefore, the performance of young subjects in lexical disambiguation tasks is better not because of their capacity to maintain both meanings of the homograph activated, but due to their capacity to inhibit one of the meanings, thus preventing the overload of WM. This model predicts cue integration difficulties for youth when the phrases are disambiguated toward the subordinate meaning. This is because they have already inhibited the subordinate meaning immediately after processing the homograph. The elderly participants will also inhibit the subordinate meaning, but their inhibitory mechanisms are less efficient than those of younger people. A paradoxical effect of inhibition deficit appears, namely that elderly subjects integrate faster the cue for ambiguous phrases disambiguated toward the subordinate meaning. For equibiased phrases the model does not predict any differences because in these phrases the discrepancy between the frequencies of using the two meanings is not sufficiently high to permit an immediate decision.

According to the specific WM resource model the WM capacity implicated in interpretive processes is not affected by aging (Waters & Caplan, 2005). As a consequence, this model does not predict any differences in the period of time needed to integrate the disambiguating cue, regardless the type of the phrase: subordinate or dominant, biased or equibiased.

Participants

Our study included thirty young participants (15 men and 15 women) and thirty older participants (17 men and 13 women). The age of the young subjects varied between 26-35 years (m = 22.41, s = 4.28). The age of the older subjects ranged between 64-77 years (m = 68.03, s = 4.17). There were no significant differences in gender distribution between age groups, the calculated value of $\chi^2 = 0.27$, df = 1, p> 0.05 being not significant. No significant differences were found regarding the level of education among the participants of the two age groups, $\chi^2 = 4.11$, df = 2, p> 0.05. In the age categories the obtained score for the evaluation of WM capacity (Reading Span Task scores) was: m = 35.97 (s = 8.35) for the older category and m = 42.46 (s = 8.56) for the young participants.

Mini Mental State Examination for each elderly participant was at least 27. Each subject had normal or corrected to normal vision. Participation in the study was conducted on a voluntary basis with the written consent of participants.

Materials

Reading Span Task (RST) – the Romanian version of this task assesses working memory capacity, imposing simultaneous information processing and storage (Just & Carpenter, 1993). It includes 60 unrelated sentences divided in 3 sets of 20 sentences each. Each set is subdivided into 5 items, each one consisting of 2 to 6 sentences. Each sentence is followed by a word (*final word*) which is semantically unrelated to it. In this task the subjects have to read each sentence and decide if it is or not grammatically correct. Then they read the word which follows the sentence. After each item, the participant has to recall all the final word of that item. The degree of difficulty of the items increases progressively, depending on the number of sentences, and the number of the word to be maintained during reading (between 2 and 6) (for a detailed description of the task see Conway et al., 2005).

Lexical Disambiguation Task (LDT) - is a Romanian version of the experimental task presented by Miyake et al. (1994). The task has been developed on the basis of 16 triplets of words each containing: one ambiguous word (a homograph, for example *boxer*) and two meanings of it (dominant - animal and subordinate - wrestler). In the first phase, the disparity factor for the two meanings of the homograph was established. For this purpose, we provided 262 subjects a list of 30 ambiguous word-triplets (target word followed by two words either synonymous or associated to the target word). The subjects' tasks were (i) to divide the value of ten points between the two meanings, and (ii) to assess on a scale from 1 to 10 the frequency of the word-usage in the spoken language. The equibiased triplets were established based on a maximum score of 3-7, and the homograph with greater discrepancies (e.g., 2-8) was included in the biased category. Using the same scores, we established which one is the dominant or subordinate meaning of the homograph. The equibiased triplets for whom the recorded score did not allow the discrimination of the dominant/subordinate meaning (e.g., 5-5) were excluded.

The stimulus sentences were generated from the 16 selected homographtriplets. For each triplet 4 phrases with similar syntactic complexity, consisting of 14 words were coined. For example, for the triplet *broască* (ambiguous word) – *yală* (subordinate meaning) – *testoasă* (dominant meaning) four sentences were built: two non-ambiguous that include words *yală* (*lock*) and *testoasă* (*turtle*), and two ambiguous that include the word *broască* (*frog*), with the meaning of *animal* (dominant meaning) or the meaning *hardware* (subordinate meaning). In the sentence, the ambiguous word (or its unambiguous counter-part) had always been on the third position, followed by three neutral words and the target word (the disambiguating cue). Thus, the 64 phrases were divided into: 32 biased and 32

equibiased sentences, of which half ambiguous (dominant or subordinate disambiguation) and half non-ambiguous (with dominant or subordinate meaning). The stimulus set also contained 40 filler sentences, which did not include ambiguous words.

For half of both types of sentences (ambiguous and non-ambiguous) a statement was developed which could be true or false.

Procedure

Data collection took place in a single session of 45-50 minutes (generally longer for the older group, but never exceeding one hour). The order of application of experimental tasks was the following: Reading Span task first, followed by the Lexical Disambiguation task.

Stimuli were presented in the center of a computer monitor, with a speed of 1 second/word. For the exposure it was used a font 90, Times New Roman. RST involves the decision of the grammatical correctness of the sentence, marked by a response, Right or Wrong (e.g., The child is goes to school - wrong). Each phrase is accompanied by a word (e.g., house). The task of the participant is to read aloud each sentence, assess the accuracy of grammar and to retain the final word, which follows each sentence. After a series of 2-6 sentences, on the computer monitor appears the instruction to recall aloud the final words respecting the order in which they were presented. The order of presentation for each item was random for each subject, the different degrees of difficulty being randomized. The measured variable was the number of words correctly reproduced. The score of each participant was calculated based on the rule of partial credit units (Conway, Kane, Bunting, Hambrick, & Wilhelm, 2005). The average duration of application was 20 minutes/participant.

The Lexical Disambiguation Task was applied in a self paced manner, using the moving windows experimental paradigm (for a detailed description of the approach see - Just, Carpenter, & Wooley, 1982). The moving windows paradigm involves browsing a phrase or a text word by word. By pressing a key on the monitor the first word of phrase appears, and with each pressing of the key new words appear while the previous one disappears. The participants' task was to read a series of sentences and then decide if the statement which follows certain phrases is true or false (for more see Miyake et al., 1994).

As a measure for sentence processing the time latency was registered for five critical regions of the sentence: disambiguating cue (cue), the first word after the cue (plus1), the second word after the cue (plus2), the words between the second and last word after the cue (inter) and the last word of the sentence (last). The average time for each given segment was calculated taken into account the number of characters included in the segment. We also registered the time needed to decide upon the correctness of the statements following half of the sentences and the frequency of correct responses.

RESULTS

Variables included in the statistical analysis were: the time needed for processing the disambiguation region (the total time of the five regions), the processing time of each region in part, the time needed to answer the statement and the correctness of this decision. Global processing time of disambiguation phase is presented in Table 1. The results were analyzed separately for biased and equibiased sentences.

Table 1

Descriptive statistics of global processing time recorded by the two age groups for biased phrases (N = 60)

	Sentence		Young Adult (N=30)	ts	Older Adults (N=30)			
Disambiguation	type	Standard Standard Rerage Standard Deviation Average Standard Deviation Average Standard Deviation Standard Standard Deviation Deviation Standard Deviation Deviation Standard Deviation Standard Deviation Deviation Deviation Standard Deviation Deviation <thdeviation< th=""> <thdeviation< th=""> <</thdeviation<></thdeviation<>	Standard error					
	Ambiguous	2680.45	1342.61	245.12	4061.3	1933.62	353	
Dominant	Non- ambiguous	2697	1365	249.22	4122.31	1774.65	324	
	Ambiguous	2614.78	1398.36	255.3	4688.91	1936.36	353.53	
Subordinate	Non- ambiguous	2530.66	1375.92	251.2	4729.68	2153.71	393.21	

The results of processing biased phrases were analyzed using a 2x2x2 ANOVA with two within groups independent variables: Sentence type (ambiguous or non-ambiguous), Disambiguation (dominant or subordinate), and Age (young adults vs. elder adults) as a between group independent variable. For the global processing time, there were three significant effects. The effect of Age was significant, F (1, 58) = 17.55, p <0.05, $\eta^2 = 0.23$, young adults processing faster (with 1770 ms) the disambiguation phase than the elderly. Also, we found an effect of Disambiguation, F (1, 58) = 8.49, p <0.05, $\eta^2 = 0.12$, which indicates that participants generally process faster (with 251 ms) the phrases disambiguated toward the dominant meaning and slower towards the subordinate one. This effect appeared only in the performance of elderly subjects, F (1, 58) = 18.16, p <0.05, $\eta^2 = 0.23$. There was no significant effect of interaction between Disambiguation x Sentence type x Age, F <1.

The effects at the global level, may be due to a strategy of young subjects to process sentences ignoring the content. To check whether such a strategy characterized the young subjects' performance, we statistically compared the number of correct answers and speed of statement processing following certain phrases. The results are presented in Table 2.

Cognition, Brain, Behavior. An Interdisciplinary Journal 13 (2009) 91-119

100

Table 2 The rate of correct responses and processing time for statements following biased phrases (N = 60)

			Young Adu	lts	Older Adults			
Disam	biguation		(N=30)			(N=30)		
Disambiguation		Average	Standard	Standard	Average	Standard	Standard	
		niterage	Deviation	Error	nveruge	Deviation	Error	
Correct	Dominant	7.1	1.88	.34	5.7	2.21	.4	
answer	Subordinate	6.73	1.98	.36	5	2.21	.4	
Latency	Dominant	2092.79	827.37	151.05	2289.64	645.93	117.93	
of the								
answer	Subordinate	1961.24	711.89	129.97	2252.06	751.98	137.29	

For the correct responses, we have recorded two significant effects: Disambiguation, F (1,58) = 5.34, p <0.05, $\eta^2 = 0.08$ and Age, F (1,58) = 10.46, p <0.05, $\eta^2 = 0.15$. These findings indicate that young people more frequently answers correctly than do elderly participants. Generally, there is a higher rate of correct responses to ambiguous dominant phrases, compared to the ambiguous subordinate ones. The value of the statistic test for the interaction effect is statistically not significant, F <1. We have not registered significant differences for time processing of each statement.

To analyze the differences in the processing time of each disambiguation region we used a 2x2x5 ANOVA, with Age as between groups independent variable (young adults vs. older adults) and two within group independent variables: disambiguating Region with five levels (disambiguate cue, 1 word after cue, 2 word after the cue, the words between the second and the last word, and last word) and Disambiguation (dominant or subordinate). The dependent variable was the difference between ambiguous phrases (disambiguated to the dominant or subordinate meaning) and non-ambiguous phrases (with dominant or subordinate meaning).

Results show no significant differences in terms of time allocated to the five regions of disambiguation, as confirmed by the absence of interactions between Age x Region x Disambiguation. Results of pair-wise comparisons, for each disambiguation region regarding the processing time of ambiguous dominant phrases, does not indicate significant differences (see Figure 1).



Figure 1

The differences between processing time of the ambiguous phrases and the same region of non-ambiguous phrase (on the left side are the results of young subjects and on the right side those of the older subjects)

To test the hypothesis formulated based on the described theoretical models, we used a 2x2x2 ANOVA with two within group independent variables: Sentence type (ambiguous or non-ambiguous) and Disambiguation (dominant or subordinate) and one between groups independent variable Age (young adults or elder adults) on the processing time of the semantic cue that allows the disambiguation of the homograph. The results are statistically not significant: we have not found any effect of Disambiguation, or Sentence type for the time of processing of the semantic cue. The only significant effect was that of Age, namely the elderly process slower the phrases compared to young subjects, F (1, 58) = 12.33, p < 0.05, $\eta^2 = 0.17$.

Processing equibiased phrases was based on a similar algorithm with that used for biased sentences. The results are presented in Table 3.

Table 3

Disambiguation	Sentence		Young Adul (N=30)	Older Adults (N=30)			
Disamoiguation	type	Average	Standard Deviaton	Standard Error	Average	Standard Deviation	Standard Error
	Ambiguous	2746.34	1466.8	267.8	4735.2	2270.57	414.54
Dominant	Non-						
	ambiguous	2751.76	1665.53	289.6	4378.64	1930.49	352.45
Subordinate	Ambiguous	2738.69	1586.23	304.08	4706.57	2050.61	374.38
	Non-						
	ambiguous	2775.80	1475.51	269.39	4750.51	1959.18	357.69

Descriptive statistics of global processing time recorded by the two age groups for equibiased phrases (N = 60)

Statistical analysis of the global processing time for the disambiguation region, indicates an effect of Disambiguation, F(1, 58) = 4.25, p < 0.05, $\eta^2 = 0.07$. We also found that young participants processed faster the sentences, regardless of their non-ambiguous or ambiguous character, F(1, 58) = 16.83, p < 0.05, $\eta^2 = 0.22$. Processing the disambiguating region of subordinate sentences requires more time (to 89.9 ms) compared to dominant sentences. This effect characterizes only the elder subject's performance but not the young participant's. The calculated value of the interaction between Age x Disambiguation is F(1, 58) = 4.14, p < 0.05, $\eta^2 = 0.07$. The statistical test calculated for the second order interaction, Age x Disambiguation x Sentence was F(1, 58) = 3.07, p = 0.08, $\eta^2 = 0.04$. The reduced value for partial eta coefficient indicates a small size effect which reduces the likelihood of an insignificant value due to a beta type error (Cohen & Cohen, 1983).

The number of correct responses to the final statements indicates an effect of Age and an effect of Disambiguation. The calculated value of statistical test for Age was F(1, 58) = 3.85, p <0.05, $\eta^2 = 0.06$, and for the Disambiguation effect is F(1, 58) = 15.42, p <0.05, $\eta^2 = 0.21$. Statistical analysis of this variable shows that young subject's shorter reaction time for disambiguating region is not due to superficial reading. They respond correctly to the final statement more frequently than older adults. Also, there is an effect of Disambiguation; the correct response rate to the final statements which follow dominant phrases is higher compared to those following subordinate phrases. This effect appears in both age groups, as indicated by the lack of interaction (see Table 4). For the response latency of final statements there is no significant effect.

Table 4

The rate of corn	rect responses and	l processing time j	for statements fol	lowing equibiased!
phrases ($N = 6$	(0)			

Disombiguotion			Young Adult (N=30)	ts	Older Adults (N=30)			
Disain	orguation	Average	Standard Deviation	Standard Error	Average	Standard Deviation	Standard Error	
Correct	Dominant	6.9	1.64	.3	5.36	1.73	.31	
Answer	Subordinate	6.43	1.86	.34	4.86	1.94	.35	
Answer	Dominant	2017.79	621.94	113.55	2349.52	619.07	113.02	
Latency	Subordinate	2041.25	708.87	129.42	2320.38	672.86	122.84	

Processing the time necessary to read each part of the disambiguating region was done using ANOVA for a 2x2x5 design. The only significant effect detected is for the Disambiguation, F (1, 58) = 4.13, p <0.05, $\eta^2 = 0.07$. This effect shows that the difference between the processing time of semantic cue in ambiguous versus non-ambiguous phrases is greater for the subordinate than for the dominant sentences.



Figure 2

The differences between processing time of the ambiguous phrases and the same region of non-ambiguous phrase (on the left side are the results of young subjects and on the right side those of the elderly subjects)

Lack of a significant interaction indicates that different regions are not processed differently by young and old subjects (see Figure 2). The only significant difference in young subjects is located at the last word t(29) = 2.65, p < 0.05, while for the elderly neither comparisons were significant (see Figure 2).

For the processing time of the disambiguation cue no effect exceeds the threshold of statistical significance. This means that the two age groups are investing the same amount of time in processing ambiguous and non-ambiguous phrases.

DISCUSSIONS

The results do not overlap completely with the predictions offered by the two general resource models, the activation (Just & Carpenter, 1992) and the inhibition models (Gunter, Wagner, & Friederici, 2003).

Corresponding to the scenario outlined in the introductory part of this paper, the main effect predicted by the model of activation is the interaction between Disambiguation x Sentence type x Age. Based on the model this second order interaction can be explained by a reduced general WM capacity of the older participants. As a direct consequence, they will be unable to maintain both meanings of a homograph, and probably will drop the one which has a lower activation level (the subordinate meaning). This cognitive failure will be visible only for biased sentences, where the difference between the activation levels of the two meanings is large. Other effects may occur or not, depending on the size of subordinate bias effect which appears in the processing of ambiguous phrases by subjects with low WM capacity (Sereno, O'Donnell, & Rayner, 2006; Simpson & Burgess, 1985).

Regarding the hypothesis based on the general inhibition capacity model, the expected results would show a second order interaction, between Disambiguation x Sentence type x Age, but this time it should be reversed. Thus, we should see a subordinate meaning bias in ambiguous phrases, but only for young participants, with high WM capacity (Gernsbacher, Keysar, Robertson, & Werner, 2001; Shivde & Anderson, 2001). Young people will need longer time to integrate the semantic cue in subordinate ambiguous sentences, because they inhibited this meaning when they reach the ambiguous word.

Analysis of global processing time of the disambiguation region for biased phrases indicates the presence of an age effect, a disambiguation effect and an interaction of the two variables. A similar result was obtained for the equibiased phrases. Such a result invalidates the inhibition model; the presence of subordinate meaning bias characterizes older adults' performance, but not those of the younger participants (with increased capacity). Data does not support the activation model, since this effect occurs in both types of sentences, ambiguous and non-ambiguous.

The recorded tendency for the global processing time can not be observed in the analysis of different parts of disambiguation region, particularly in the disambiguation of the semantic cue. This is confirmed by the absence of significant differences between different regions of disambiguation. Also, differences in processing time of the semantic cue in ambiguous and non-ambiguous phrases, between dominant and subordinate meaning has not attained statistical significance. This effect characterizes both age groups. Results show that for the disambiguating cue the only significant effect is the age effect. Thus, the results show an overall slowing of the older people in integrating semantic cue but this effect is not specific to any region, or any kind of sentence. Such a general slowing can be easily accommodated with the existing empirical research results (Salthouse, 1996; Salthouse, 2001).

The presence of the subordinate bias effect was not observed neither in younger nor in older people. These data question the validity of the inhibition hypothesis as an explanation of lexical disambiguation. According to this model the absence of such an effect can be explained only if there were no differences between the efficiency of the inhibitory mechanism between young and old people. Such a conclusion is clearly contradicted by data from literature which sustain the presence of an inhibitory decline in elderly population (Gernsbacher & Faust, 1991; Gernsbacher & Robertson, 1995).

The obtained results seem to favor the model of specific WM resources which predict no differences between age categories, but could explain differences in processing ambiguous and non-ambiguous sentences. According to this model, lexical disambiguation does not imply a general executive mechanism, like activation capacity or inhibitory efficiency (Zacks & Hasher, 1998; Waters & Caplan, 2005). There is a specific WM resource that seems to be allocated to interpretive processes, and is not affected by aging (Waters & Caplan, 1997; Waters & Caplan, 2001).

There is one more possibility that could explain the missing of a second order interaction: the lack of effect in processing the disambiguation cue, and interaction with age is due to a small distance between the ambiguous word and match (Engle, Carullo, & Cantor, 1992; Miyake & Shah, 1999). It is possible that there are no specific WM resources, and there is a general activation capacity. Older adults have deficits in maintaining the activation level of information for short duration of time, but this deficiency wouldn't be observed because the distance between the homograph and the semantic cue was short (Turner & Engle, 1986). Therefore, dominant and subordinate meanings are still above the threshold of the WM capacity when the cue is reached. The same explanation could explain the lack of significant effects registered for equibiased sentences.

Experiment 2

Apparently, the results of Experiment 1 support the specific resource WM model. According to this model separate cognitive resources are implicated in interpretive and post-interpretive processes. The obtained results ruled out the possibility that lexical disambiguation implies a general inhibitory mechanism. But we could not exclude the possibility that there is a general activation WM capacity which could mediate the relation between an ambiguous verbal stimulus and a semantic context. To test this possibility we replicated the study, using a modified version of the lexical disambiguation task.

According to the general activation capacity model, young participants will be not affected (or will be affected to a lesser extent than older participants) by increasing the distance between the homograph and the semantic cue, because they have enough resources to maintain activated both meaning until they reach the disambiguating cue. Contrary to this, increasing the distance between the ambiguous word and the disambiguation cue will increase the integration time of the semantic cue only in older subjects, when biased ambiguous phrases are disambiguated towards the subordinate meaning. In equibiased phrases, the effect will be present regardless of the sense of disambiguation.

Participants

This study included thirty four young participants (18 men and 16 women) and thirty six older participants (18 men and 18 women). The age of young subjects varied between 26-35 years (m = 23.32, s = 4.74). The age of older subjects group ranged between 66-75 years (m = 70.35, s = 5.23). There were no significant differences in gender distribution between groups defined on the basis of age, $\chi^2 = 0.06$, df = 1, p> 0.05 was not significant. No difference was significant regarding the level of education among the participants of the two age groups, $\chi^2 = 1.22$, df = 2, p> 0.05. In the age categories the obtained score for the evaluation of WM capacity (Reading Span Task scores) was: m = 23.33 (s = 8.94) for the elder category and m = 41.44 (s = 8.02) for the young participants.

Mini Mental State Examination for each elderly participant was at least 27. Each subject had normal or corrected to normal vision. Participation in the study was conducted on a voluntary basis with the written consent of participants.

Materials

Reading Span task (RST) - the same as used in Experiment 1.

Lexical Disambiguation task (LDT) – the same experimental task as used in Experiment 1, but this time the stimulus sentences contained 18 words. In the sentence, the ambiguous word (or its unambiguous counter part) has always been on the third position followed by eight neutral words and the target word (the disambiguating cue). As in Experiment 1 the 64 phrases were divided into: 32 biased and 32 equibiased sentences, of which half ambiguous (dominant or subordinate disambiguation) and half non-ambiguous (with dominant or subordinate meaning). The stimulus set consisted also of 40 filler sentences, which did not include ambiguous words. Half of both types of sentences (ambiguous and non-ambiguous) were associated with a statement, which could be true or false.

Procedure

As in Experiment 1 data collection took place during a single session with a duration of 55-60 minutes (generally longer for the older group, but never exceeded 70 minutes). The order of application of experimental tasks was the following: Reading Span task and Lexical Disambiguation task.

As a measure for sentence processing the time latency was registered for five critical regions of the sentence: disambiguating cue (cue), the first word after the cue (plus1), the second word after the cue (plus2), the words between the second and last word after the cue (inter) and the last word of the sentence (last). The average time for each given segment was calculated taken into account the number of characters included in the segment. We also registered the time needed to decide upon the correctness of the statements following half of the sentences and the frequency of correct responses.

RESULTS

As in Experiment 1, the variables included in the study were: global processing time for processing the disambiguation region (the total time of the five regions), the processing time of each region in part, the time needed to answer the statement and the correctness of this decision. Global processing time for the disambiguation region is presented in Table 5. The results for biased and equibiased phrases were analyzed separately.

The data presented in Table 5 were processed with the 2x2x2 ANOVA with two within group independent variables: Sentence type (ambiguous or non-ambiguous) and Disambiguation (dominant or subordinate), and Age (adult or youth) as a between group independent variable. The global processing time shows

Cognition, Brain, Behavior. An Interdisciplinary Journal 13 (2009) 91-119

Age effect F (1,68) = 12.72, p <0.05, η^2 = 0.15. Young adults process faster (with 1062 ms) the disambiguation region than the older participants.

Table 5

Descriptive analysis of global processing time for the two age groups of biased phrases (N=70)

			Young Adult	Older Adults				
Disambiguation	Sentence	(N=34)			(N=36)			
Disamoiguation	type	Average	Standard	Standard	Average	Standard	Standard	
		8-	Deviation	Error	8-	Deviation	Error	
	Ambiguous	2674.06	799.02	137.03	3716.01	1605.57	267.59	
Dominant	Non-	2594.58	924.73	158.59	3626.1	1643.5	273.91	
	ambiguous		/ =					
	Ambiguous	2583.55	818.15	140.31	3669.29	1600.84	266.8	
Subordinate	Non- ambiguous	2346.96	719.58	123.4	3439.4	1551.43	258.57	

Also there is an effect of the Sentence type, ambiguous sentences are processed more slowly (144.88 ms) than non-ambiguous phrases. The value of statistical test calculated for this difference is F (1,68) = 7.62, p <0.05, $\eta^2 = 0.1$. The effect of Disambiguation is statistically significant, F (1,68) = 21.81, p <0.05, $\eta^2 = 0.24$ which shows a longer processing time (158.97 ms) for subordinated phrases then for dominant ones. The last significant effect recorded for these data is the interaction between Sentence type x Age, F (1,68) = 3.83, p <0.05, $\eta^2 = 0.05$. This interaction suggests an increase in processing time for ambiguous phrases, only for elderly subjects. There was no significant interaction between Disambiguation x Sentence type x Age, F <1.

Table 6

The rate of correct responses and processing time for statements following biased phrases (N = 70)

Disambiguation			Young Adul (N=34)	ts	Older Adults (N=36)			
		Average	Standard deviation	Standard Error	Average	Standard Deviation	Standard Error	
Correct	Dominant	7.23	1.61	.27	6.44	2.6	.43	
answer	Subordinate	7.14	1.39	.23	5.91	2.33	.38	
Latency of the	Dominant	2369.72	787.13	134.99	2442.92	915.62	152.6	
answer	Subordinate	2288.27	594.25	101.91	2328.88	820.96	136.82	

The statistical analysis testing the involvement of young subjects in the processing of sentences shows no significant effect, young subjects responding correctly to the same number of statements as the older participants. Similar results

were obtained for processing time, young subjects process statements as quickly as the older, and results are presented in Table 6.

To analyze the differences in the processing time registered for each disambiguation region, we used a 2x2x5 ANOVA, with one between groups independent variable, Age (young or elder) and two within group independent variables, disambiguation Region with five levels (disambiguation cue, 1 word after cue, the second word after the cue, the words between the second and the last word and last word) and Disambiguation (dominant or subordinate). The dependent variable was the difference between ambiguous phrases (disambiguation to the dominant or the subordinate meaning) and unambiguous phrases (dominant or subordinate).

Processing the different disambiguation regions, we found an effect of Disambiguation, F (1,68) = 3.84, p <0.05, $\eta^2 = 0.05$. The most important finding is the significant effect for the interaction of Disambiguation x Age, F (1,68) = 2.45, p <0.05, $\eta^2 = 0.13$, which means that older subjects processes different the disambiguation regions, but this effect is limited to the disambiguation cue. Comparing processing time for the disambiguation regions of subordinate and dominant sentences, resulted no significant differences (see Figure 3).

Results show no difference for the time allocated for the five disambiguation regions, sustained by the absence of interactions between Age x Region or Age x Disambiguation. This is also confirmed by pair wise comparisons calculated for each of the processing times of the Disambiguation region for dominant and subordinate phrases.



Figure 3

The differences between processing time of the ambiguous phrases and the same region of non-ambiguous phrase (on the left side are the results of young subjects and on the right side those of the elderly subjects)

To test this hypothesis we used a 2x2x2 ANOVA that includes two independent within group variables: Sentence type (ambiguous or non-ambiguous) and Disambiguation (dominant or subordinate) and one independent between

group variable, Age (young or elder). The dependent variable was the processing time of the disambiguation cue. Results indicate the presence of two significant effects, the Sentence type and the interaction between Sentence type x Age. The results are statistically significant, F (1,68) = 33.56, p <0.05, $\eta^2 = 0.33$, respectively F (1,68) = 7.05, p <0.05, $\eta^2 = 0.09$. Results show that only subjects with reduced WM capacity need longer time for processing the disambiguation cue.

Statistical analysis of equibiased phrase follow the same algorithm as the biased ones, a 2x2x2 ANOVA includes two within group independent variables: Sentence type (ambiguous or non-ambiguous) and Disambiguation (dominant or subordinate) and one between group independent variable, Age (young or elder). The results are presented in Table 7.

Statistical comparison of the global processing time for disambiguation regions indicates an effect of Age, F (1,68) = 11.56, p <0.05, η^2 = 0.14. This means that older subjects are slower in processing the disambiguation region, than the younger participants. More important in terms of experimental hypothesis is the interaction between Sentence type x Age, F (1,68) = 4.15, p <0.05, η^2 = 0.06.

Analysis of the number of correct responses to the statement which follow certain sentences indicates an effect of Age and an effect of Disambiguation. The value for the first effect is F (1,68) = 15.33, p <0.05, $\eta^2 = 0.18$ and for the second effect is F (1,68) = 30.01, p <0.05, $\eta^2 = 0.3$.

Table 7

		Young Adults			Older Adults			
Disambiguation	Sentence	(N=34)			(N=36)			
Disamoiguation	type	Average	Standard Deviation	Standard Error	Average	Standard Deviation	Standard Error	
	Ambiguous	2599.15	731.82	125.5	3842.3	1652.9	275.48	
Dominant	Non- ambiguous	2589.49	781.72	134	3654.95	1671.49	278.58	
	Ambiguous	2633	780.52	133.85	3727.52	1682.49	280.41	
Subordinate	Non- ambiguous	2787.03	1355.48	232.46	3586.07	1621.14	270.19	

Descriptive analysis of global processing time for the two age groups regarding the processing of equibiased phrases

Number of correct responses to the statement following the sentences, are higher for the dominant sentences, compared to those which follow subordinate phrases. The statistically significant effect of Age shows that young people give more correct answers then the elders (see Table 8). This means that better performance (shorter processing time) for young subjects in the disambiguating region are not due to their superficial reading, their correct response rate is better than for the older participants. For the response latency no significant effect was found.

Disambiguation			Young Adult (N=34)	ts	Older Adults (N=36)			
		Average	Standard	Standard	Average	Standard	Standard	
		_	Deviation	Error	-	Deviation	Error	
Correct	Dominant	7.58	1.2	.2	5.83	.33	2.	
answer	Subordinate	6.47	1.52	.26	5.25	.32	1.96	
Latency	Dominant	2243.04	612.75	105.08	2364.07	121.8	730.8	
of the answer	Subordinate	2248.28	659.64	113.12	2394.46	125.01	750.06	

Table 8	
Correct response rate and processing time for statements following the sentences	(N=70)

To analyze each diambiguation region we used a 2x2x5 ANOVA. The only significant effect is for Age, F (1,68) = 4.15, p <0.05, η^2 = 0.06. The other two variables did not differ significantly, F>1. If we compare two by two the disambiguation phases, there are no significant differences (see Figure 4). The differences between the processing time for the same region in the ambiguous and unambiguous phrases do not differ for the dominant and subordinate sentences.



Figure 4

The differences between processing time of the ambiguous phrases and the same region of non-ambiguous phrase (on the left side are the results of young subjects and on the right side those of the elderly subjects)

For the processing time of disambiguation cue, there were two significant effects, the Age, F (1,68) = 10.87, p <0.05, $\eta^2 = 0.13$ and the interaction between Sentence type x Age, F (1,68) = 4.95, p <0.05, $\eta^2 = 0.07$. This means that the older group process differently ambiguous and unambiguous phrases, but this effect is not present in younger subjects.

DISCUSSIONS

In Experiment 2 we modified the distance between the ambiguous word and the disambiguating cue. According to the general activation model such a manipulation of the capacity would increase WM load, and the processing time of semantic cue. This effect will be more pronounced in older group, because they have lower activation capacity of WM.

The statistical analysis of global processing time for biased phrases show an effect of Age, the younger adults processing the disambiguation region faster than older people. Another important effect is represented by the Sentence type x Age, which means that the effect of Age is significant only for ambiguous phrases; unambiguous sentences being processed in the same manner by the two age groups. There is also an effect of Disambiguation, which shows that the difference between processing time for subordinate and dominant phrases is statistically significant. This main effect does not interact with the effect of other variables. Analyzing the processing time for equibiased phrases shows a similar pattern, an effect of Age and an interaction effect between Sentence type x Age. But, we didn't find a significant effect for the Disambiguation. The lack of Disambiguation effect is understandable, taken into account that for these phrases the difference between the activation level of dominant and subordinate meaning is not so large (Zurif, Swinney, Prather, Wingfield, & Brownell, 1995).

In sum, we can say that the analysis of the global processing time of disambiguating region does not confirm the model of specific interpretive resources (Caplan & Waters, 1999). Based on these results it seems more probable that lexical disambiguation implies a general WM capacity (Miyake, Carpenter, & Just, 1994). This conclusion is sustained by the results offered by analyzing each part of the disambiguating region, which reveals an interaction between Disambiguating region x Age. This result sustains the hypothesis that younger and older participants process differently each part of the disambiguating region. An important region that is processed differently is the semantic cue, which shows an effect of Age x Sentence type.

A major problem for the general activation model seems to be that we did not find a second order interaction between Sentence type x Disambiguation x Age, at global or local level. The question is to what extent is such a result still consistent with a prediction regarding the general activation model? Analyzing the processing time for the semantic cue in ambiguous phrases indicates an effect of Sentence type. This means that the elderly have processed more slowly the semantic cue in ambiguous sentences regardless of the direction of disambiguation. In other words said, they processed in the same way the biased and the equibiased phrases.

The question is how could a behavior, characteristic to the young adults, appear in the older adults? The only reason consistent with these data is that young people are those who maintain both meanings activated, thus resulting similar

processing times for both types of biased and equibiased phrases. The elderly, on the contrary, do not maintain any meaning, and systematically will have higher processing time for both types of phrases. This is the answer that explains why there is no second order interaction and there are "similarities" in the two groups for processing ambiguous subordinate and dominant phrases.

GENERAL DISCUSSIONS

Lexical access refers to all psycholinguistic mechanisms involved in accessing meaning of a word. Lexical access can be reduced to meaning access only if a word has a single meaning (Balota, d'Arcais, & Rayner, 1990). If a word has several meanings, lexical access necessarily includes a process of lexical disambiguation (Tanenhaus & Spivey-Knowlton, 1996; Tabossi, 1996).

Numerous studies show that there are no age differences in meaning access, even if a word has multiple meanings (Rayner & Pollatsek, 1989). Lexical decision tasks showed no differences between younger and older people in time needed to access lexical meaning (Bowles & Poon, 1985). Also, some studies showed that in both age categories performance is affected in the same way by the presence of semantic cue, and by the degree of association between the target and cue (Balota & Duchek, 1988; Bowles, 1989; Laver & Burke, 1993). Studies regarding the mechanism of lexical disambiguation are far more controversial.

As noted above, access meaning reflects an automated process that does not suffer decline with aging, but aging seems to affect disambiguation. This effect is more pronounced when the distance between the semantic context and the ambiguous word increases. Such deficit can explain failures of older people in establishing referential relations of a pronoun (Morrow, Altieri, & Leirer, 1992) and in disambiguating ambiguous words, like homographs (Dagerman, MacDonald, & Harm, 2006).

Another linguistic context which implies lexical disambiguation is one in which the disambiguation is made after processing the ambiguous stimulus (Miyake, Carpenter, & Just, 1994). Regardless the disambiguating context is processed before or after the ambiguous word, both tasks require maintaining information in WM capacity (Daneman & Carpenter, 1980). The main question is what type of WM resources are involved in lexical disambiguation, general resources or specific resources? On the one hand, there are models that consider lexical access as interpretive processes, implying specific WM resources (Waters & Caplan, 1995, 1996; Rochon, Waters, & Caplan, 2000). On the other hand, are those models that describe lexical disambiguation as a process affected by the interaction of information from different processing levels (e.g., thematic, syntactic, etc). As a consequence these models assume the implication in lexical disambiguation of a general WM system, which could handle such information (Just & Carpenter, 1992).

The current study aims to determine the nature of WM resources implied in lexical disambiguation. One of the basic assumptions of our study is that the capacity of WM declines with age (Salthouse, 1996; Ferrer-Caja, Crawford, & Bryan, 2002). We considered that in case general WM resources are involved in lexical disambiguation, WM decline will create difficulties in lexical disambiguation. With regard to the underlying general WM mechanisms, we tested predictions of two hypotheses, that of inhibition (Gunter & Friederici, 1999) and the activation (Just & Carpenter, 1992; Miyake, Carpenter, & Just, 1994; Just, Carpenter, & Keller, 1996). However, if the resources used by interpretive processes are independent of the processes involved in post-interpretive processes, age will not affect lexical disambiguation (Waters & Caplan, 1997; Waters & Caplan, 2005).

The obtained results excluded the possibility that there are specific WM resources allocated specifically to interpretive processes. Such resources should not decline with age, but we found an interaction between Disambiguation and Age, which clearly shows that the implicated resources are affected by aging. Consequently, the presented results support the involvement of general WM resources in lexical disambiguation. The results support the implication of a general activation mechanism, and explain the observed age differences in lexical disambiguation due to a decline of the activation mechanism. However, the nature of this mechanism is still not clear, it can be a general activating attention mechanism of central executive (Hasher, Zacks, & May, 1999; Lustig, May, & Hasher, 2001) or a mechanism of short term maintenance, such as phonological buffer processes (Baddeley, 2002). Since the executive components suffer a more serious decline with aging, it is more probable that these components cause the reported effects (Just & Carpenter, 1992).

Cognitive inhibition is an important factor in explaining age differences in WM capacity, but the experiment results seem to rule out a possible implication of cognitive inhibition in the process of lexical disambiguation. We consider that the presented results do not deny any involvement of this mechanism in the disambiguation process, but show that the degree of association of an ambiguous word with its meanings cannot be a correct selection criterion (May & Hasher, 1998; Lustig, Hasher, & Tonev, 2001; Wagner & Gunter, 2004). This conclusion is sustained by studies sustaining the idea that when semantic context precedes the ambiguous word, the meaning-activation is immediately followed by the inhibition of the incompatible meaning (Shivde & Anderson, 2001; Paul, 1996; Oden & Spira, 1983).

In conclusion, we can say that the data provided by this study support the involvement of general WM resources in lexical disambiguation. Maintaining the activation level of the two meanings characterize young subjects' performances. It appears that the decline of WM capacity reduce the ability of elder adults to maintain the activation level of both meanings of the homograph. As a consequence, older people, like their younger counter parts, will process dominant

and subordinate ambiguous phrases in the same manner. But opposing to younger participant, this result is explained by the fact that they fail to maintain any meaning of the homograph.

REFERENCES

- Balota, D. A., Flores d'Arcais, G. B., & Rayner, K. (Eds.) (1990). *Comprehension Processes in Reading*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.
- Balota, D. A., & Duchek, J. M. (1988). Age-related differences in lexical access, spreading activation, and simple pronunciation. *Psychology and Aging*, 3, 84-93.
- Baddeley, A. D. (2002). Is working memory still working? *European Psychologist*, 7, 85-97. Reprinted from *American Psychologist*, 56, 851-864.
- Bagner, D. M., Melinder, M. R., & Barch, D. M. (2003). Language comprehension and working memory language comprehension and working memory deficits in patients with schizophrenia. *Schizophrenia Research*, 60, 299–309.
- Binder, K. S., & Morris, R. K. (1995). Eye movements and lexical ambiguity resolution: Effects of prior encounter and discourse topic. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 1186–1196.
- Bowles, N. L. (1989). Age and semantic inhibition in word retrieval. *Journal of Gerontology*, 44, 88-90.
- Bowles, N. L., & Poon, L. W. (1985). Effects of priming in word retrieval. Journal of Experimental Psychology: Learning, Memory, & Cognition, 11, 272-283.
- Cantor, J., & Engle, R. W. (1993). Working memory capacity as long-term memory activation: An individual differences approach. *Journal of Experimental Psychology: Learning, Memory and Cognition, 19*, 1101-1114.
- Caplan, D., & Waters, G. S. (1999). Verbal working memory and sentence comprehension. *Behavioral Brain Sciences, 22*, 114–126.
- Clark, H. H., & Clark, E. V. (1977). *Psychology and Language*. New York: Harcourt Brace Jovanovich.
- Cohen, J. D, Barch, D. M., Carter, C. S., & Servan-Schreiber, D. (1999). Schizophrenic deficits in the processing of context: Converging evidence from three theoretically motivated cognitive tasks. *Journal of Abnormal Psychology*, 108, 120-133.
- Cohen, J. & Cohen, P. (1983). Applied multiple regression/correlation analysis for the behavioral sciences (2nd ed.). Hillsdale, New Jersey: Lawrence Erlbaum Associates.
- Conrad, C. (1974). Context effects in sentence comprehension: A study of the participative lexicon. *Memory & Cognition, 2,* 130–138.
- Conway, A., Kane, M., Bunting, M., Hambrick, D & Wilhelm, O. (2005) Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin and Review*, 12, 769-786.
- Dagerman, K. S., MacDonald, M. C., & Harm, M. (2006). Aging and the use of context in ambiguity resolution: Complex changes from simple slowing. *Cognitive Science*, 2, 311-345.
- Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. Journal of Verbal Learning and Verbal Behavior, 19, 450-466.

- De Beni, R., & Palladino, P. (2000). Intrusion errors in working memory tasks: Are they related to reading comprehension ability? *Learning and Individual Differences*, 12, 131-143.
- Dopkins, S., Morris, R. K., & Rayner, K. (1992). Lexical ambiguuity and eye fixations in reading: A test of competing models of lexical ambiguuity resolution. *Journal of Memory and Language*, 25, 613–624.
- Duffy, S. A., Kambe, G., & Rayner, K. (2001). The effect of prior disambiguuating context on the comprehension of ambiguuous words: Evidence from eye movements. In D. Gorfein (Ed.), On the consequences of meaning selection (pp. 27-43). Washington, DC: American Psychological Association.
- Engle, R. W., Cantor, J., & Carullo, J. J. (1992). Individual differences in working memory and comprehension: A test of four hypotheses. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18*, 972-992.
- Federmeier, K. D., McLennan, D. B., De Ochoa, E., & Kutas, M. K. (2002). The impact of semantic memory organization and sentence context information on spoken language processing by younger and older adults: An ERP study. *Psychophysiology*, 39, 133–146.
- Ferrer-Caja, E., Crawford, J. R., & Bryan, J. (2002). A structural modelling examination of the executive decline hypothesis of cognitive aging through reanalysis of Crawford et al.'s (2000) data. *Aging, Neuropsychology and Cognition*, 9, 231-249.
- Frattali, C., Hanna, R., McGinty, A. S., Gerber, L., Wesley, R., Grafman, J., & Coelho, C. (2006). Effect of prefrontal cortex damage on resolving lexical ambiguuity in text. *Brain and Language*, 6, 231-256.
- Gernsbacher, M. A., & Faust, M. E. (1991). The mechanism of suppression: A component of general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*, 245–262.
- Gernsbacher, M. A., Keysar, B., Robertson, R. R. W., & Werner. N. K. (2001). The role of a suppression and enhancement in understanding metaphors. *Journal of Memory and Language*, 45, 433-50.
- Gernsbacher, M. A., Varner, K. R., & Faust, M. (1990). Investigating differences in general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 430-445.
- Gunter, T. C., & Friederici, A. D. (1999). Concerning the automaticity of syntactic processing. *Psychophysiology*, *36*, 126-137.
- Gunter, T. C., Wagner, S., & Friederici, A. D. (2003). Working memory and lexical ambiguuity resolution as revealed by ERPs: A difficult case for activation theories. *Journal of Cognitive Neuroscience*, 15, 643-657.
- Hagoort, P., & Brown, C. (1994). Brain responses to lexical ambiguity resolution and parsing. In C. Clifton, L. Frazier, & K. Rayner (Eds.), *Perspectives on sentence* processing (pp. 45-80). Hillsdale, NJ: Erlbaum.
- Hasher, L., Zacks, R. T., & May, C. P. (1999). Inhibitory control, circadian arousal, and age. In D. Gopher & A. Koriat (Eds.), Attention & Performance, XVII, Cognitive Regulation of Performance: Interaction of Theory and Application (pp. 653-675). Cambridge, MA: MIT Press.
- Hopkins, K. A., Kellas, G., & Paul, S. T. (1995). Scope of word meaning activation during sentence processing by young and older adults. *Experimental Aging Research*, 21, 123-142.

- Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review*, 99, 122-149.
- Just, M. A., & Carpenter, P. A. (1993). The intensity dimension of thought: pupillometric indices of sentence processing, *Canadian Journal Experimental Psycholology*, 47, 310-39.
- Just, M. A., Carpenter, P. A., & Keller, T. A. (1996). The capacity theory of comprehension: New frontiers of evidence and arguments. *Psychological Review*, 103, 773–780.
- Just, M. A., Carpenter, P. A., & Wooley, J. D. (1982). Paradigms and Processes in Reading Comprehension. *Journal of Experimental Psychology: General*, 111, 228-238.
- Klepousniotou, E. (2002). The processing of lexical ambiguity: Homonymy and polysemy in the mental lexicon. *Brain and Language*, *81*, 205-223.
- Laver, G. D., & Burke, D., M. (1993). Why do semantic priming effects increase in old age? A meta – analysis, *Psychology and Aging*, 8, 34-43.
- Lustig, C., May, C. P., & Hasher, L. (2001). Working memory span and the role of proactive interference. *Journal of Experimental Psychology: General*, 130, 199-207.
- Lustig, C., Hasher, L., & Tonev, S. T. (2001). Inhibitory control over the present and the past. *European Journal of Cognitive Psychology*, *13*, 107-122.
- Madden, C. J., & Zwaan, R. A. (2006). Perceptual representation as a mechanism of lexical ambiguity resolution: an investigation of span and processing time. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 32*, 1291-1303.
- May, C. P., & Hasher, L. (1998). Synchrony effects in inhibitory control over thought and action. *Journal of Experimental Psychology: Human Perception and Performance*, 24, 363-379.
- Miyake, A., Carpenter, P. A, & Just, M. A. (1994). A capacity approach to syntactic comprehension disorders making normal adults perform like aphasic patients. *Cognitive Neuropsychology*, *11*, 671–717.
- Miyake, A., & Shah, P. (Eds.) (1999). Models of Working Memory: Mechanisms of Active Maintenance and Executive Control. New York: Cambridge University Press.
- Monsell, S., Doyle, M. C., & Haggard, P. N. (1989). Effects of frequency on visual word recognition tasks: Where are they? *Journal of Experimental Psychology: General*, 118, 43–71.
- Morrow, D., Altieri, P., & Leirer., V. (1992). Narrative organization, presentation mode, and referent choice strategies. *Experimental Aging Research*, 18, 75–84.
- Murray, W. S., & Forster, K. I. (2004). Serial mechanisms in lexical access: The rank hypothesis. *Psychological Review*, 111, 721–756.
- Oden, G. C., & Spira, J. L. (1983). Influence of context on the activation and selection of ambiguous word senses. *Quarterly Journal of Experimental Psychology, Section* A, 35, 51–64.
- Onifer, W., & Swinney, D. A. (1981). Accessing lexical ambiguuities during sentence comprehension: Effects of frequency of meaning and contextual bias. *Memory and Cognition*, 9, 225-236.
- Paul, S. T. (1996). Search for semantic inhibition failure during sentence comprehension by younger and older adults. *Psychology and Aging*, 11, 10-20.
- Rayner, K., & Pollatsek, A. (1989). *The psychology of reading*. Englewood Cliffs, New York: Prentice-Hall

- Rodd, J., Gaskell, G., & Marslen-Wilson, W. (2002). Making sense of semantic ambiguuity: semantic competition in lexical access. *Journal of Memory and Language*, 46, 245-266.
- Rochon, E., Waters, G. S., & Caplan, D. (1994). Sentence comprehension in patients with Alzheimer's disease. *Brain and Language*, *46*, 329–349.
- Rochon, E., Waters, G. S., & Caplan, D. (2000) Working memory and sentence comprehension in patients with Alzheimer's disease: Evidence from multiple measures of working memory capacity and sentence comprehension. *Journal of Speech, Language and Hearing Research, 43*, 395-413.
- Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103,* 403–428.
- Salthouse, T. A. (2001). Structural models of the relations between age and measures of cognitive functioning. *Intelligence*, 29, 93-115.
- Seidenberg, M. S., Tanenhaus, M. K., Leiman, J. M., & Bienkowski, M. (1982). Automatic access of meanings of ambiguuous words in context: Some limitations of knowledge based processing. *Cognitive Psychology*, 14, 489-537.
- Sereno, S. C., O'Donnell, P. J., & Rayner, K. (2006). Eye movements and lexical ambiguuity resolution: Investigating the subordinate bias effect. *Journal of Experimental Psychology: Human Perception and Performance*, 32, 335-350.
- Simpson, G. B., & Burgess, C. (1985). Activation and selection processes in the recognition of ambiguous words. *Journal of Experimental Psychology: Human Perception & Performance*, 11, 28-39.
- Shivde, G., & Anderson, M. C. (2001). The role of inhibition in meaning selection: Insights from retrieval-induced forgetting. In D.S. Gorfein (Ed.), On the consequences of meaning selection: Perspectives on resolving lexical ambiguity (pp. 175–190). *Washington, DC: American Psychological Association*.
- Speranza, F., Daneman, M., & Schneider, B. A. (2000). How aging affects the reading of words in noisy backgrounds. *Psychology and Aging*, 15, 253-258.
- Swaab, T., Brown, C.M., & Hagoort, P. (2003). Understanding words in sentence contexts: The time course of ambiguuity resolution. *Brain and Language*, 86, 326-343.
- Swinney, D. A. (1979). Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning and Verbal Behavior*, 18, 545–569.
- Tabossi, P. (1996). Cross-modal semantic priming. *Language and Cognitive Processes*, 11, 569–576.
- Tanenhaus, M. K., & Spivey-Knowlton, M. J. (1996). Eye-tracking. Language and Cognitive Processes, 11, 583-588.
- Titone, D., Levy, D., & Holzman, P. S. (2000). Contextual insensitivity in schizophrenic language processing: Evidence from lexical ambiguuity. *Journal of Abnormal Psychology*, *109*, 761–767.
- Turner, M. L., & Engle, R. W. (1986). Working memory capacity. Proceedings of the Human Factors Society, 30, 1273-1277.
- Vos, S. H., Gunter, T. C., Schriefers, H., & Friederici, A. D. (2001). Syntactic parsing and working memory: The effects of syntactic complexity, reading span, and concurrent load. *Language and Cognitive Processes*, 16, 65–103.
- Vos, S. H., & Friederici, A. D. (2003). Intersentential syntactic context effects on comprehension: The role of working memory. *Cognitive Brain Research*, 16, 111-122.

- Wagner, G. S., & Gunter, T. C. (2004). Determining Inhibition: Individual Differences in the 'Lexicon Context' Trade-Off During Lexical Ambiguity Resolution in Working Memory. *Experimental Psychology*, 51, 290-299.
- Waters, G. S., Caplan, D., & Rochon, E. (1995). Processing capacity and sentence comprehension in patients with Alzheimer's Disease. *Cognitive Neuropsychology*, 12, 1-30.
- Waters, G. S., & Caplan, D. (1996). Processing resource capacity and the comprehension of gardenpath sentences. *Memory and Cognition.* 24, 342-355.
- Waters, G. S., & Caplan, D. (1997). Working memory and on-line sentence comprehension in patients with Alzheimer's disease. *Journal of Psycholinguistic Research*, 26, 377–400.
- Waters, G. S., Rochon, E., & Caplan, D. (1998). Task demands and sentence comprehension in patients with Dementia of the Alzheimer's Type. *Brain and Language*, *62*, 361-397.
- Waters, G. S. & Caplan, D. (2001). Age, working memory and on-line syntactic processing in sentence comprehension. *Psychology and Aging*, 16, 128-144.
- Waters, G. S., & Caplan, D. (2005). The relationship between age, processing speed, working memory capacity and language comprehension. *Memory*, 13, 403-413.
- Zacks, R. T., & Hasher, L. (1998). Cognitive gerontology and attentional inhibition: A reply to Burke and McDowd. *Journal of Gerontology*, *52*, 274-283.
- Zurif, E., Swinney, D., Prather, P., Wingfield, A. & Brownell, H. (1995). The allocation of memory resources during sentence comprehension: evidence from the elderly. *Journal of Psycholinguistic Research*, 24, 165-182.
- Zwitserlood, P. (1989). The locus of effects of sentential-semantic context in spoken-word processing. *Cognition*, *32*, 25–64.