Framing Space: Alzheimer’s Disease and Object Location in Brazilian Portuguese

Jan Edson Leite (jan.edson@academico.ufpb.br)
Universidade Federal da Paraíba. Bloco E – CCHLA – Campus I – Cidade Universitária, João Pessoa (PB) Brazil

Abstract

This paper delves into the possible correlations between cognitive impairment due to Alzheimer’s Disease and differences in the ways spatial relations are decoded by groups of individuals with and without AD. We tested participants’ judgments of spatial scenes coded according to intrinsic, relative or undissociated Frames of Reference, ground rotation and use of a locative construction. We found significant differences in the costs of processing spatial information which were considerably higher in elderly and AD groups. On the other hand, judgment ratings reveal that those groups tend to maintain the same Frame of Reference applied by health young individuals to resolve the spatial ambiguity. Furthermore, a general preference for non-relative Frames of Reference was found among participants, all native speakers of Brazilian Portuguese.

Keywords: Spatial Cognition; Alzheimer's Disease; Frame of Reference; Brazilian Portuguese

Introduction

This paper explores the interconnections between Frames of Spatial Reference (FoR) and their respective linguistic encodings to predict whether spatial reasoning is affected in the process of aging healthily or with cognitive impairment, either by increased costs of processing of visual and linguistic information necessary to interpret spatial scenes, or by changes in the cognitive mechanisms used to conceptualize relations between objects in a certain spatial context. Previous studies on FoR (Levinson, 1996, 2004; Majid et al., 2004; Haun et al., 2006) focused on neurotypical young subjects.

Considering that individuals with Alzheimer's disease (AD) are said to present impaired linguistic and cognitive mechanisms for understanding spatial scenes as well as for decoding information about the visuospatial properties of objects (American Psychiatric Association, 1994), we proposed a study which not only describes differences in the processing cost of spatial interpretation among two groups of elderly individuals (healthy and with AD) contrasted to a control group (college students), but also compares the preferences of the studied groups for different ways of encoding space in a under-represented language, Brazilian Portuguese (BP).

We also reflect on the difficulties in linguistic comprehension displayed by elderly subjects with cognitive impairments, and deficits in visuo-spatial processing and its representation in language, as a basis of comparison to the cognitive mechanisms of information encoding and interpretation of spatial content, and to test how they affect the spatial description of object relations in our study groups.

Linguistic and Cognitive impairments in AD

Alzheimer's disease (AD) is considered the most prevalent dementia, with about 50% to 75% of cases found in older adults over 65 years (Herrera et al., 2002; Nitrini et al., 2004). According to DSM-IV-TR4 (APA, 1994), difficulties in linguistic and non-linguistic cognitive functions, such as memory, visuospatial abilities, executive functions, and decision making, are considered the main signs of cognitive decline caused by Alzheimer's disease (Peña-Casanova et al., 1994; Robles & Peña-Casanova, 2002).

McKhann et al (2011) suggest that when affected by a dementia, the individual displays cognitive and/or behavioral (neuropsychiatric) symptoms related to the domains and functions of language and spatial cognition, among which we highlight deficits in visuospatial skills, such as (a) difficulties in recognizing common faces and objects; (b) problems in finding objects in the center of their visual field, despite preserving good visual acuity; (c) inability to operate simple instruments or dress themselves; as well as impaired language functions which include struggles in accessing common words during speech, hesitations, and spelling errors in writing.

Regarding the domains of language and visuospatial cognition, subjects with non-amnestic presentation of AD have cognitive impairments of linguistic order, in which the most common deficits are those related to difficulty in finding words; and of visuospatial order, in which spatial cognition is the most compromised. In these cases, the patient has agnosia for objects, impaired face recognition (prosopagnosia), simultanagnosia (Balint syndrome[1]), and alexia[2]. Deficits in other cognitive domains are also present, as well as executive dysfunction, in which there is impaired reasoning and judgment, as well as difficulty in problem solving. In addition to visuospatial deficits, severe impairment of spatial cognition produces effects on cognitive functions such as decision-making, logical reasoning, and working memory, which are linked to the task of understanding and interpreting the spatial relationships described in this study.

[1] Syndrome described by Rezső Bálint, which encompasses severe neuropsychological impairments such: inability to perceive more than one stimulus in the visual field (simultanagnosia); difficulty in fixing the eyes (oculomotor apraxia); and the inability to move the hand to reach a specific object using vision (optic ataxia)

[2] Difficulty in integrating visual perceptions for word identification (global comprehension).

In M. Goldwater, F. K. Anggoro, B. K. Hayes, & D. C. Ong (Eds.), *Proceedings of the 45th Annual Conference of the Cognitive Science Society*.

Aging and Language Comprehension

Ferreira (2014) characterizes the effects of aging on sentence comprehension by considering non-linguistic variables (processing speed, working memory, and inhibition). Her study suggests that aging produces an effect on quality of sentence comprehension by elderly people, with respect to lexical and syntactic processing, mediated by working memory impairment and processing speed. In other studies (Mansur et al., 2005; Parente, 2006), the results reveal that impairments in other cognitive abilities, such as working memory, visual difficulties, and attention maintenance; and in linguistic abilities, such as difficulty in accessing the lexicon and semantic representations, bring greater impairment to reading comprehension when compared to auditory comprehension.

The process of linguistic comprehension activates, in semantic memory, access to words and the recognition of their meanings, which contribute to meaningful reading. When this is affected by slow reading processing (Burke & Shafto, 2008) and by a deficit in spatial orientation, there may be a loss of meaning of the initial words before the final words of the sentence are integrated, resulting in impaired comprehension of the word, sentence, or text.

Difficulties with semantic memory are also observed in AD patients. In studies of semantic memory activation, when performing judgment tasks to associate a category of words with their respective pictures, subjects showed difficulties in categorizing objects, as well as in learning new categories. The more familiarity one has with the target category, the easier the association process is, and the less representative the exemplars of the category are, the less efficient the recognition process is (Grossman et al., 2003).

Frames of Spatial Reference (FoR)

Frames of Reference (Levinson, 1996, 2004; Majid et al., 2004; Haun et al., 2006) are connected to how a given spatial scene is put into perspective. If we say that (1) "a ball is in front of the car", our understanding of this scene can be based on the spatial relationship between the two objects, which is organized to adopt a perspective between Figure (ball) and Ground (car), aligned with an Intrinsic FoR, i.e., the subject assumes the functional structure of the "car" (sides, canonical front, rotation etc.) as a vantage point for the use of the spatial term "in front of".

On the other hand, by saying something like (2) "the chair is in front of the wall", the spatial relationship between the two objects may be conceptualized according to the vantage point of the speaker. In this case, the spatial arrangement is centered on the conceptualizer (EGO). This type of FoR is called Relative. In Brazilian Portuguese (BP), both intrinsic and relative FoR are coded in ambiguous locative terms such as “em frente de” (in front of); “atrás de” (behind); “à direita de” (to the right); “à esquerda de” (to the left). To decode a spatial description as intrinsic, BP speakers lack unambiguous linguistic constructions and therefore should probably rely on properties of the Ground object (its distinguishable sides) or on Ground rotation (Feist & Leite, 2022).

An Absolute FoR, in its turn, would impose a perspective on Figure and Ground, which conveys a spatial relationship between subjects and objects with their fixed geographical boundaries. Some languages, such as Portuguese and English, would connect this FoR with cartographic representations of magnetic poles in sentences like (3) "I live in the Northeast of Brazil". Other languages, however, would base their spatial arrangements on other geocentric structures, such as local relief (4) "The hot water faucet is the one [location-aligned] uphill" (Brown & Levinson 1993; 2000). A good part of the languages whose preference for an absolute frame of spatial reference has been described (Bowden, 1997; Haviland, 1998; Brown & Levinson, 1993, 2000), seem to use spatial coordinate structures independent of cartographic models.

While some scholars (Halligan et al., 2003; Wang & Spelke, 2002) consider Relative Frames of Reference as more primary than Intrinsic ones and spatial cognition as inherently egocentric, Majid et al. (2004) question whether relative FoRs are more natural, and whether children acquire/learn them more easily, concluding that "the available evidence, although scarce, does not support this hypothesis" (Majid et al., 2004, p. 112). Egocentric coordinates are strongly related to Kantian approach to space and by neglecting psychology and neurocognition as well as linguistic diversity, we risk establishing an ethnocentric approach to spatial understanding in language and cognition.

Other studies have shown that relative Frames are less primary and have no automatic use in many languages. Most evidence comes from cross-cultural variation in studies of European language acquisition, as well as from describing adult use of non-European languages. This is the case in Johnston's (1988) study of children acquiring English, Italian, Serbo-Croatian, and Turkish who do not demonstrate the relative uses of "front / back" (e.g., in (5) "the ball is in front of the tree") until about five years of age. The intrinsic uses appear a year or more early, for example, in sentences such as (6) "[the ball is] in front of the man." Other studies focus on cross-cultural differences in cognitive strategies, such as spatial reasoning across languages (Majid et al., 2004).

Haun et al (2006), while focusing on the cultural and linguistic variability of spatial cognition, suggest that there may be a phylogenetic bias for the use of a certain type of cognitive strategy in "great apes" including humans, and that the ontogeny of language and culture may mask some innate biases of the species. Their argument, based on empirical evidence, argues for the impact of language and culture on primate cognitive biases rather than a nativist approach or the *tabula rasa* hypothesis. The authors argue that, contrary to Kantian assumptions of the priority of egocentric spatial reasoning, our inherited mode of cognitive operation is not egocentric, but preferentially uses environmental cues as a common reference between objects.

In our study, described below, we integrate discussions about the linguistic-cultural functioning of Frames of

Reference with questions about their cognitive role in spatial reasoning and in the interpretation of visuo-spatial scenes, to verify whether speakers' preference for a type of spatial representation is aligned with the choice of Intrinsic or Relative FoR, as well as whether this preference is maintained when speakers age healthily or when they develop cognitive impairments due to AD. Furthermore, considering the deficits in visuo-spatial coding in language, we are interested in knowing whether the processing of information used in spatial description has its cost and quality affected.

Methods

To find possible correlations between cognitive deficits and differences in comprehension of spatial relations among healthy and AD participants, we designed an experiment to assess judgement of fit between spatial scenes and their corresponding linguistic descriptions by three groups of participants:

Group A = 24 college students (graduate and undergraduate levels) aged 18-42 years (M= 28.5), 15 female, 9 male, without cognitive impairment according to the CDR[3] and mental state examination (mini-mental)[4].

Group B = 06 healthy individuals aged 51-75 (M=64.2), 4 female, 2 male, without cognitive impairment according to the CDR and mini-mental, 4 to 11 years of formal education.

Group C = 06 individuals diagnosed with probable AD and grades between 0.5 (2) and 2.0 (4) of cognitive impairment according to the Clinical Dementia Rating (CDR), aged 60 to 84 years (M=72.5), 2 female, 4 male, 4 to 11 years of formal education.

Our purpose in this study is to compare results between groups to assess the difference in processing costs of spatial information between healthy subjects and subjects with probable AD and between young and elderly subjects; to describe whether the frames of reference used by young and healthy subjects (group A) are the same as those adopted by the experimental groups (groups B and C); and to describe which relations are the most affected in tasks of spatial decoding by subjects with cognitive impairment.

Materials and Procedures

This test rates acceptability judgments of linguistic descriptions consistent with spatial depictions of two objects (Figure and Ground) displayed on an invisible grid of 5 x 5 frames. The Ground is a simple, monochromatic image of an airplane, centered on the screen (frame 3x3), in bird's eye view, which is randomly oriented in four directions (rotations). The Figure (a coin) appears on each trial in one of the 24 remaining frames of the grid. The participant's task is to judge whether the coin location on each trial is consistent with its linguistic encoding, and rate the acceptability of one of the four sentences (a-d, below) shown at the bottom of the screen, immediately after the image (fig. 1):

(a) A coin is in front of the plane
(b) A coin is behind the plane
(c) A coin is to the right of the plane
(d) A coin is to the left of the plane

Figure 1: Visual stimulus. Ground (airplane) in 180º rotation and Figure (coin) presented in the 5x2 grid position. Participants must judge whether one of the sentences (a-d) displayed after the visual stimulus is acceptable.

The acceptability judgment is made by using our adaptation of the Likert scale (1932), composed of numerical items (1 to 7) aligned horizontally below the sentence. Each number in the scale represents an evaluation previously trained by the participant, so that 1 means that the relation between picture and sentence is completely unacceptable, and 7 means that this relation is completely acceptable.

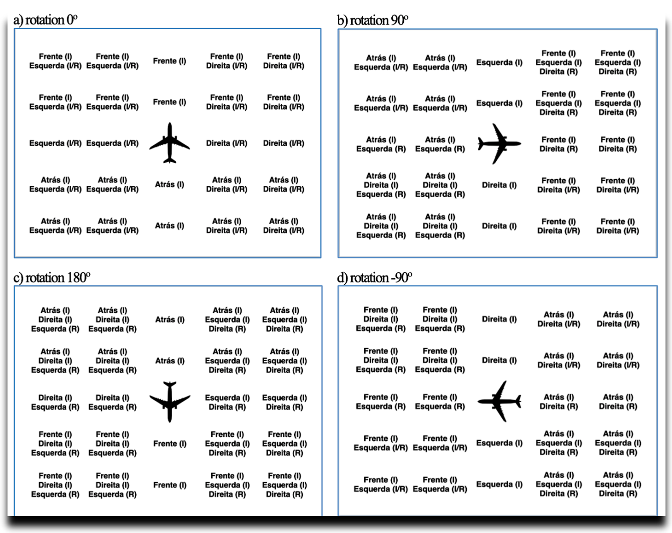

Figure 2: Stimulus presentation control grid. Each locative term (esquerda, direita, frente, atrás) and FoR (I = intrinsic; R = relative; I/R = not dissociated) indicate a single choice of interpretation of the presented spatial scene.

[3] Clinical Dementia Rating – CDR (Hughes et al., 1982; Morris, 1993). This score is useful for characterizing and monitoring the patient's level of impairment/dementia and extends from 0 to 3 (0 = Normal; 0.5 = very mild dementia; 1 = mild dementia; 2 = moderate dementia; 3 = severe dementia).

[4] The MMSE is a cognitive assessment scale for patients at risk of dementia. Scores above 25 are considered normal. Mild cognitive loss is suspected when the score is >21 and <24 points; Moderate= >10 and <20; and Severe = less than or equal to 9.

Considering the number of locations on the grid (24 possibilities), the number of rotations of the Ground (4 = 0º; 90º, 180º and -90º degrees), the occurrence of a spatial descriptor (esquerda, direita, frente, atrás) licensed by the intrinsic or relative Frame of Reference (Fig. 2) and excluding repetitions of the same locative term for different spatial configurations of a given Frame, the final number of stimuli administered was 204. The experiment was written in Python language and run in Psychopy in a 15-inch MacBook Pro computer, retina screen. We measured Response Rating (hits on a scale of 1 to 7) and Response Time – RT (interval between the onset of stimulus presentation and the moment the participant hits a rating button, in seconds).

Results and Discussion

To compare the processing costs of interpreting spatial scenes among the subjects studied, we grouped the analyzable factors into two categories: *linguistic-cognitive*, involving: a) the terms used for projective spatial relations (esquerda/direita; frente/atrás), which were judged as acceptable or not for the scenes shown to the participants; and b) the Frames of Spatial Reference (relative FoR = R, intrinsic FoR = I or intrinsic/relative non-dissociated FoR = I/R) that structure the spatial reasoning necessary for understanding and interpreting these scenes. The other category refers to *visuospatial properties* of objects, analyzed in this paper only in terms of: c) rotation of Ground, in four levels specified as 0º; 90º, 180º and -90º degrees. We then analyzed the time participants took to respond to the stimuli judgments and compared the results obtained with each of the factors (a-c, above) to highlight their correlations.

Global Processing Costs In the comparison between groups A, B and C we found quite different response times (RT) among the participants. The healthy elderly (B) had a mean RT (M = 11.627; SD = 5.13) twice as high as the RT of group A, college students (M = 6.500; SD = 2.04), partially suggesting that the variable age may influence the cost of performing the task. The elderly with cognitive impairment (group C), on the other hand, had response times three times higher in comparison with group A (M= 20.100; SD= 10.338), according to Table 1 below. In this case, in addition to the effect of age, already found in the comparison between groups A and B, the time cost may be attributed to the comprehension deficits due to AD presented by group C. The difference in performance in the comparison between the groups suggests an increasing processing cost as age rises (contrast between A and B), which is further raised by the cognitive impairment caused by probable AD.

Table 1: Response Time of Groups Compared.

	N	Mean	Std Dev	Variance	Median
Group A	204	6,500546	2,049305	4,199651	5,956875
Group B	204	11,62752	5,137253	26,39137	10,05125
Group C	204	20,10024	10,33837	106,8819	18,9407

Fig. 3 below illustrates the extent of the difference in the groups' response times, indicating that as the age range advances between group A (M= 28.5) and groups B (M=64.2) and C (M=72.5), there is a significant increase in the average time spent performing the task. However, the age variable seems to have no effect in the comparison between groups B and C (similar age group), whose difference in response time to the task suggests an even higher effort attributed to the presence of cognitive impairment, as shown by the comparison of the averages between these groups.

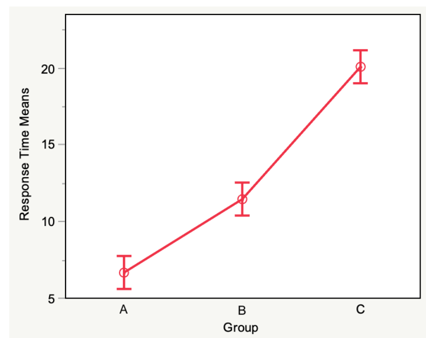

Figure 3: Mean Response Time of Groups.

RT by Frame of Reference We verified that there were no significant effects in the comparison between the response time of groups (A, B and C) and the Frame factor, in its three levels (I and I/R and R). The averages of each group presented a small variation in their distribution by the levels of the FoR, keeping the general costs already described in table (1) above. For group A, the mean RTs for the Intrinsic (M=6.335), Intrinsic/Relative (M=6.995) and Relative (M=6.560) Frames had no significant variation ($\chi 2$ (df=2) = 1.7411, p <0.4187). The other groups followed a similar pattern of variation. These results may indicate that the effects of age and cognitive impairment on the costs of the judgment task by the speakers affect spatial reasoning at any Frame levels.

RT by Locative Term In comparing the RTs of the groups with the effects of the locative term factor (direita, esquerda, frente, atrás) no differences were found in Groups B and C, which maintained equivalent means for the four levels of the terms. In group B, the levels "direita" (M=11.278), "esquerda" (M=11.816), "atrás" (M=12.511) and "frente" (M=10.992) showed no variation among themselves, suggesting that the effects of the variable age, described in the general analysis of the groups' RTs, are the main responsible for the increase in the linguistic-cognitive processing cost of spatiality in this group. For group C, the means for "à direita" (M=18.840), "à esquerda" (M=19.553), "atrás" (M=21.935) and "em frente" (M=21.066) seem to indicate that the linguistic-cognitive understanding of spatiality is more seriously affected by the deficits resulting from the onset of Alzheimer's dementia than by the effects of the linguistic factor term, which also did not vary significantly in its four levels.

Within Group A, however, the pairs of terms: esquerda-direita (left-right), frente-esquerda (front-left), and atrás-esquerda (back-left) showed significant variation from each other in terms of RT for solving the spatial judgment task. College students took longer to judge acceptable scenes that were structured with locative "left" (M=7.023; SD=2.00) than with "right" (M=6.469; SD=2.35). The term "à esquerda" also produced slower responses in comparison with "atrás" (M=5.942; SD=1.60) and "em frente" (M=6.296; SD=1.88). This variation ($\chi2$ (df=3) = 10.5202, p<0.0146) seems to indicate that certain spatial relations (left-right, for example) are developed later than others (Johnson, 1988; Johnston & Slobin, 1979), which may cause a more delayed processing of the information needed for a spatial decision.

RT by Rotation When comparing the response time of the groups with the visuospatial factors, such as the Rotation of Ground, we noticed that the effects of the rotation levels produced variations in the RT of group A, but not of groups B and C. The variation within group A, however, maintained significant effects. The response time for interpreting scenes with 180º rotation (M=7.038) was significantly higher relative to scenes with 0º rotation (M=6.197) and -90º rotation (M=5.977), ($\chi2$ (df=3) = 10.1493, p <0.0173), but varied little with respect to 90º rotation (M=6.636). These differences between the groups suggest that: a) rotation does indeed influence the normal processing costs of spatial scenes, as significant between-level variations were found in group A; b) the effects of age and cognitive impairment on RT in groups B and C and the sample size do not allow us to gauge precisely how much rotation may influence the processing costs of these groups.

Thus, from the point of view of the linguistic-cognitive and visuo-perceptual phenomena that act on spatial reasoning, we found that, in isolation, they have limited impact on the costs of normal processing of information necessary for understanding space by groups A and B, but do not seem to affect by themselves, in our sample, the response times of group C. However, their correlation with typical aging may produce substantial changes in time spent to make a spatial decision. Furthermore, the cognitive decline caused by language and spatial impairments in Alzheimer's disease appears to increase this cost beyond the age variable, producing effects on the spatial cognition of the elderly with deficits associated with probable AD.

Rating by Frames of Reference Descriptive values (table 2) for the differences between participants' judgments according to the Frame of Reference factor revealed significant variations in judging the acceptability of scenes. College students judged more acceptable scenes interpreted from a non-dissociated Intrinsic/Relative Frame (M=5.376; SD=0.42) or Intrinsic (M=4.877; SD=0.90) and less acceptable scenes structured according to a Relative Frame (M=2.382; SD=0.29), $\chi2$ (df=2) = 115.7222, p <0.0001. These three levels of the Frame category were also judged differently in groups B and C, in which scenes compatible with both I/R frames were judged as most acceptable (group B, M=4.756; group C, M=5.578), followed by scenes compatible with an Intrinsic Frame (group B, M=4.155; group C, M=4.473), while scenes matching Relative Frame were judged the least acceptable (group B, M=2.869; group C, M=3.128). These results suggest that the structuring of spatial reasoning seen in group A (control), holds true in the other groups at different ages and with cognitive impairments. The sample size, however, is insufficient to compare the extent of this maintenance, even though we found an increase in spatial information processing costs between groups.

Table 2: Ratings by Groups for each FoR.

Frame	Group	N	Mean	Std Dev	Median	Variance
I	A	124	4,877016	0,904403	4,625	0,817944
	B	124	4,155242	1,343682	4,125	1,80548
	C	124	4,473925	1,428112	4,6	2,039504
I/R	A	36	5,376157	0,426955	5,333333	0,18229
	B	36	4,756944	0,773411	4,75	0,598165
	C	36	5,578704	0,873095	6	0,762295
R	A	44	2,382576	0,292188	2,375	0,085374
	B	44	2,869318	0,751914	3	0,565374
	C	44	3,12803	1,49642	2,416667	2,239274

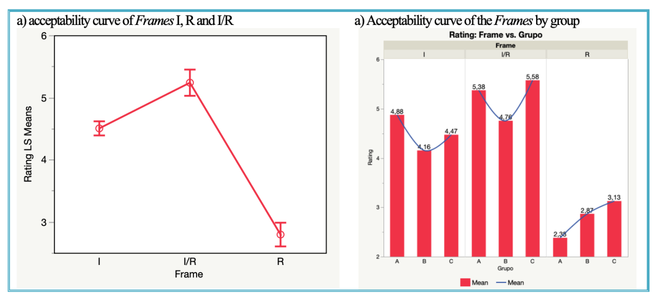

Figure 4: Judgment of acceptability of spatial scenes structured by Frames.

Fig. 4 above reveals the clear preference of all groups for an interpretation of the spatial scene structured according to a FoR that does not dissociate the vantage points centered on the speaker/conceptualizer or on the Ground object in the spatial scene (I/R), followed by the preference for an intrinsic FoR that takes the vantage point of the Ground object as the basis for decoding the spatial relation. In 4a) we observe that the mean acceptance of scenes with non-dissociated (intrinsic/relative) interpretation is significantly different from the mean of intrinsic interpretations (Dif.M=97.095; SD=19.304; p<0.0001) and that both exceed the half limit (3.5) of the acceptability scale values (ranging from 1 to 7). In 3 b) we sort these judgments by participant groups. The evaluation curve is maintained between the groups, although group B shows a tendency to assign lower acceptability values to levels I and I/R compared to the other groups. Follow up studies on this trend might reveal more about spatial reasoning of AD speakers.

Rating by Locative Term In the analyses of the Term factor and its effects for judging the acceptability of spatial scene descriptions, we compared the means of all groups and found no significant variation in the acceptability of scenes described by the terms "à direita" (M=4.354; SD=1.47); "à esquerda" (M=4.219; SD=1.43); "atrás" (M=4.407; SD=1.29) and "em frente" (M=4.046; SD=1.36), $\chi2$ (df=3) = 6.0746, p <0.1080. This pattern of variation was repeated in group A ($\chi2$ (df=3) = 1.0070, p <0.7995 and Group B. In group C, the means reveal a difference in the values assigned by participants when evaluating descriptions that contained ambiguous interpretations between the front-right and front-back pairs. In this group, descriptions with the term "em frente" (M=3.908) were judged less acceptable than descriptions with "à direita" (M=4.813), "à esquerda" (M=4.454) and even "atrás" (M=4.056). This variation seems to suggest that age effects in group B and the linguistic-spatial impairments typical of AD may interfere with the decision making required by the task. This trend, however, requires more robust samples from both groups to be confirmed.

Thus, it is possible to infer that the linguistic-cognitive factors Frame, and Term have a strong influence on the speaker's spatial reasoning and affect the judgment and understanding of spatial relations and their respective linguistic description. In all groups, Relative Frames had the highest rejection rates revealing a preference of the Brazilian Portuguese speaker for an intrinsic (isolated or not dissociated) conceptualization of object location. This general preference was maintained in all groups regardless of age or level of cognitive impairment of the participants. There is, however, a slight tendency for group B to assign lower acceptability values to intrinsic Frames, and for group C to judge relative descriptions more acceptable, which may reflect on changes in mechanisms of spatial reasoning for these groups.

Rating by Rotation When comparing the mean judgments of the participants with the visuospatial factors such as rotation of the Ground, the contrasts between the level 0º of Rotation and levels 90º, 180º and -90º are highly significant in all groups, indicating that as the Ground object leaves its neutral position (0º) the difficulty in keeping it as a basis for the location of the Figure increases and the value of acceptability of the scene decreases.

The mean acceptance of scenes in which Ground is in rotation 0 are higher in all groups (A: M=5.090; B: M=4.5; C: M=4.999) in comparison with the other rotation levels, producing significant variation for group A ($\chi2$ (df=3) = 13.2651, p <0.0041). These results suggest the relevance of the spatial property of the Ground rotation for the Figure localization task, as well as the possibility of maintaining this type of reasoning even in the presence of cognitive impairments, when processing costs are usually higher.

In the Fig. 5(a) below it is possible to visualize the descending curve of the average ratings attributed by all groups to the descriptions with different rotations (0º, 90º, 180º) with a slight elevation of 270 degrees (Rotation -90º).

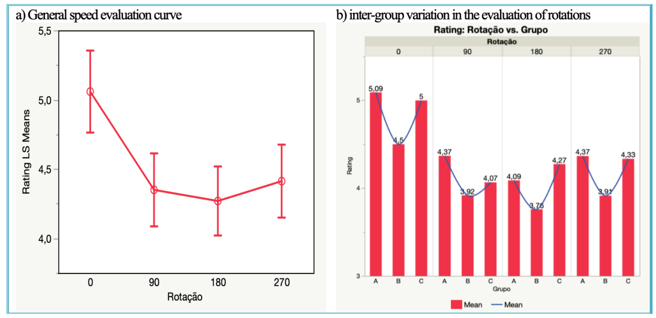

Figure 5: Acceptability rating of spatial scenes structured by different rotations of Ground.

In 5b), in addition to the overall downward pattern, intergroup variations for each rotation are observed, forming a U-shaped curve in which the rating averages of groups A and C contrast with the downward pattern of the averages of group B at all rotation levels. This alignment in the mean acceptability ratings between groups A and C also contrasts with RT results and suggests the need of a follow-up research not found in the literature on mental rotation (Shepard & Metzler, 1971; Robertson et al., 1987; Asakura & Inui, 2011; Kaltner & Jansen, 2016) that generally focus on reaction times. Possible developments include issues of cognitive development and working memory involved in mental rotation; disambiguation of object-centered or egocentric rotation; as well as correlations between rotation and projective (left/right) spatial relations.

Some Conclusions

The overall understanding of spatial scenes and the acceptance of their descriptions were affected by FoR, locative term and rotation of Ground. Although Groups B and C showed a significantly high temporal demand to solve a decoding task, speakers in these groups maintained a general pattern of acceptance of Intrinsic Frames of Reference, even if the rejection of relative FoR is lower than in Group A. Acceptance of spatial descriptions encoded by locative terms also showed significant contrasts between the groups in disambiguation tasks. While Group A tended to have a greater acceptance of descriptions “in front of/behind” compared to “right/left”, Groups B and C rejected "in front of" descriptions, opting for “behind and left/right” to disambiguate the scene. The acceptance of descriptions in which the Ground was in neutral rotation (0º) was significantly higher for all groups compared to the other rotations, indicating a similar pattern of spatial reasoning between the groups, although the costs to reach this result are quite different. The differences between the response times for each group, as noted, indicate that processing the same information is more costly in groups B and C, with group C making a greater effort to perform the same task, possibly due to difficulties in working memory and information processing that structure spatial reasoning.

Acknowledgments

I am indebted to Michele Feist who supervised part of this study during my research stay at her Language and Cognition Lab, at UL Lafayette and with whom I had prolific discussions about spatial reference. I am most grateful to Suellen Andrade, who shared with me the AD participants under study on her own research project. Thanks to my graduate and undergraduate students who helped more than I could ever expect while conducting this research: Mábia Toscano, Thalita Aureliano, Francisco Sousa, Andrea Gomes. I also would like to thank the participants of this study who donated their time to science an endured a lot of minutes watching coins fly over planes.

References

Acredolo, L. (1988) Infant mobility and spatial development, in J. Stiles-Davis, M. Kritchevsky & U. Bellugi (Eds.) *Spatial cognition: Brain bases and development*, Hillsdale, NJ: Lawrence Erlbaum.

American Psychiatry Association (1994) *Diagnostic and Statistical Manual of Mental Disorders*: DSM-IV.

Asakura & N.; Inui, T. (2011) Disambiguation of mental rotation by spatial frames of reference. *Perception*, 2(5), 477-485.

Bowden, J. (1997) The Meanings of Directionals in Taba. In G. Senft (Ed.) *Referring to Space: Studies in Austronesian and Papuan Languages*. Oxford: Clarendon Press.

Brown, P.; Levinson, S.C. (1993) "Uphill" and "downhill" in Tzeltal. *Journal of Linguistic Anthropology*. 3(1),46-74.

Brown, P.; Levinson, S.C. (2000) Frames of spatial reference and their acquisition in Tenejapan Tzeltal. In: Nucci, L.; Saxe, G.; Turiel, E. (Eds.) *Culture, thought, and development*. Mahwah, NJ: Lawrence Erlbaum.

Burke, D. M.; Shafto, M. A. (2008) Language and Aging. In: F. I. M. Craik, & T. A. Salthouse (Eds.) *The Handbook of Aging and Cognition*. New York: Psychology Press.

Carlson-Radvansky, L.A.; Irwin, D.E. (1993) Frames of reference in vision and language: Where is above? *Cognition*. 46 (3), 223-244.

Feist, M.; Leite, J. (2022). An Intrinsic Preference: Using Frames of Reference to Locate Objects in Brazilian Portuguese. Chicago. *Association for Psychological Science Annual Convention.*

Ferreira, A. L. S. (2014) *Effects of aging after middle age on sentence comprehension: a study of mediation by non-linguistic cognitive factors*. Master's dissertation, Faculty of Psychology and Education Sciences, Catholic University.

Grossman M; Koenig P; Glosser G; Devita C; Moore P; Rhee J; Detre J; Alsop D. (2003) Neural basis for semantic memory difficulty in Alzheimer's disease: an fMRI study. *Brain*. 126, 292-311.

Halligan P, Fink G, Marshall J, Vallar G. (2003) Spatial cognition: evidence from visual neglect. *Trends Cogn. Sci.* 7, 125-133.

Haun, D. B. M.; Rapold, C. J.; Call, J.; Janzen, G; Levinson, S. C. (2006) Cognitive Cladistics and Cultural Override in Hominid Spatial Cognition. *Proceedings of The National Academy of Sciences*. 103 (46), pp. 17568-17573.

Haviland, J.B. (1998) Guugu Yimithirr Cardinal Directions. *Ethos*. 26, 25-47.

Herrera E; Caramelli P; Silveira A; Nitrini R. (2002) Epidemiologic survey of dementia in a community dwelling Brazilian population. *Alzheimer Dis Assoc*. 16 (2), 103-108.

Hayward W; Tarr M. (1995) Spatial language and spatial representation. Cognition. 55 (1), 39-84.

Hughes C; Berg L; Danziger W; Coben L; Martin R.(1982) A new clinical scale for the staging of dementia. J *Psychiatry*. 140, 566-72.

Johnston, J. R. (1988) Children's Verbal Representation of Spatial Location. In Stiles-Davies, J. et al., (Eds) *Spatial Cognition,* Erlbaum Language Sciences.

Johnston, J.R.; Slobin, D. (1979) The development of locative expressions in English, Italian, Serbo-Croatian and Turkish. *Journal of Child Language*. 6, 529-45.

Kaltner S; Jansen P. (2016) Developmental Changes in Mental Rotation: A Dissociation Between Object-Based and Egocentric Transformations. *Adv Cogn Psychol*. 12(2), 67-78.

Levinson, S.C. (1996) Language and space. *Annual Review of Anthropology*. 25, 353-382.

Levinson, S.C. (2003) *Space in Language and Cognition:* Explorations 37 in Cognitive Diversity. Cambridge: Cambridge University Press.

Majid, A.; Bowerman, M.; Kita, S.; Haun, D. B. M.; Levinson, S. C. (2004) Can language restructure cognition? The case for space. *TRENDS in Cognitive Sciences*, 8 (3), 108-114.

Mansur, L. L; Carthery, M.T.; Caramelli, P; Nitrini, R.(2005) Language and Cognition in Alzheimer's Disease. *Psicologia: Reflexão e Crítica*. 18 (3), 300 - 307.

Mckhann G; Drachman D; Folstein M; Katzman R; Price D; Stadlan, E M. (2011) The diagnosis of dementia due to Alzheimer's disease: Recommendations from the National Institute on Aging and the Alzheimer's Association workgroup. *Alzheimer's & Dementia*. 7 (3), 263-269.

Morris, J. (1993) The Clinical Dementia Rating (CDR): current version and scoring rules. *Neurology*: 43(11), 2412-4.

Nitrini, R.; Caramelli, P.; Herrera, E.; Bahia, V.S.; Caixeta, L.F.; Radanovic, M.(2004) Incidence of dementia in a community dwelling Brazilian population. *Alzheimer Dis Assoc*. 18(4), 241- 6.

Parente, M. A. M. P. (2006) *Cognição e Envelhecimento.* Porto Alegre: Artmed.

Peña-Casanova, J.; Bermejo F; Alom J; Del Ser T; Acarín N; Manubens J; Gabriel R. (1994) Multicenter register of index cases of dementia. *Neurology*. 9 (9), 401-06.

Robertson, L. C., Palmer, S. E., & Gomez, L. M. (1987) Reference frames in mental rotation. *Journal of*

Experimental Psychology: Learning, Memory, and Cognition, 13(3), 368-379.

Robles, A; Peña-Casanova, J. (2002) *Evaluación neuropsicológica y funcional de la dementia.* Barcelona: JR Prous.

Shepard, R. N.; Metzler, J. (1971) Mental rotation of three-dimensional objects. *Science*, 171 (3972), 701-703.

Wang, R.F; Spelke, E.S. (2002) Human spatial representation: insights from animals. *Trends Cogn. Sci*. 6, 376-382.