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Introduction
Recursion is a fundamental characteristic of human grammar (Hauser, Chomsky, Fitch, 2002), and is described mathematically by a function that takes its own output as input (Clark 2006). The main purpose of this research is to study the processing of language recursion in different stages of Alzheimer's Disease (mild, moderate) compared to age-matched healthy controls. We would like to map the recursive abilities (syntactical embedding and 'theory of mind' embedding) of the Alzheimer's Disease (AD) participants.

Materials and methods
In total, 6 participants participated in this study. AD persons (n=6) were sub-grouped according to the severity of the dementia syndrome: they were midly to moderately demented as gauged by Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975) and ADAS-Cog (Rosen et al, 1984). All AD participants met the DSM-IV and ICD-10 (WHO, 1993) criteria for probable Alzheimer's Disease (American Psychiatric Association, 2000).
The ELA: Everyday Life Activities (Stark 1994) test were used to ask the following structural type of questions (Banreti 2010):
   a) Type 1: What is X doing in the picture? The question does not require that any of its own constituents should be involved in the structure of the answer.
   b) Type 2: What does X like/ hate/want/. . . every morning? The answer should be structurally linked to the question and involve:
   (i) a subordinate clause in direct object role, introduced by a recursive operation and signalled by a subordinating conjunction, or
   (ii) the verb of the question and its infinitival direct object, or
   (iii) a definite noun phrase (NP) in the accusative.
   c) Type 3: What can be the most entertaining/unpleasant/urgent thing for X to do? The answer should be structurally linked to the question and involve:
   (i) a subordinate clause in subject role, introduced by a recursive operation and signalled by a subordinating conjunction, or
   (ii) a bare infinitive subject, or
   (iii) a definite (NP) in the nominative.
   d) Type 4: What can X think /say/remind Y of / ask Y to do etc.? The structurally linked answer must be:
   (i) a clause embedded under an introductory formula, introduced by a recursive operation and signalled by a subordinating conjunction.
   (ii) We accepted also the 'theory of mind' type embedding.

Results

The percentage of structurally linked and unlinked answers of the patients are summarized in Table 1.

Question	mild AD			moderate AD		
	structurally linked	structurally linked, agrammatic	structurally unlinked	structurally linked	structurally linked, agrammatic	structurally unlinked
Type 1	95	1,5	3,5	96,3	-	3,7
Type 2	72,5	1	26,5	68,8	-	31,2
Type 3	79,5	-	20,5	81,3	-	18,7
Type 4	86	-	14	63,8	3,7	32,5

Table 1. Percentage of structurally linked and unlinked answers

In the moderate stage of AD are increased the number of structurally not linked answers.

The recursive and non recursive answers of the AD patients are summerized Table 2.

Question	Mild AD		Moderate AD		Normal control	
	R	NR	**R**	NR	**R**	NR
Type 1	**1**	99	**1,3**	98,7	**0**	100
Type 2	**6,5**	93,5	**2,5**	97,5	**3**	97
Type 3	**12,3**	87,7	**12,5**	87,5	**15**	85
Type 4	**62**	38	**60,5**	40	**57**	43

Table 2. Percentage of recursive (R) and non recursive (NR) answers

The structurally linked anwers in Type 4 question are summerized in Table 3.

Category / Participants	Mild AD	Moderate AD	Normal control
Sentence with subjunctive mood	16	37,5	12
'Theory of mind' type embedding	22	2	31
Subordinating conjunction + 'Theory of mind' type embedding	7	2	12
Subordinating conjunction + descriptive Clause	35	32,5	36
Subordinating conjunction with subjunctive mood	20	26	9

Table 3. Type 4 questions: percentage of all structurally linked answers

The results of the test revealed that the 'theory of mind' type embeddings are decreasing, while the structural recursion are increasing in moderate stage of the disease.

Conclusions
The formal structural recursion may be more unimpaired in mild and moderate Alzheimer's Disease, while the 'theory of mind' type embeddings are impaired from the moderate stage of the disease. The intact formal structural recursion and the restricted 'theory of mind' type embeddings in moderate Alzheimer's can be argue dissociation between syntactical recursion and 'theory of mind' type recursion.

References
American Psychiatric Association (2000) Diagnostic and statistical manual of mental disorders (4th ed., text. rev.) Washington, DC: Author.
Bánréti, Zoltán (2010) Recursion in aphasia, Clinical Linguistics & Phonetics, 24/11, 906 – 914.
Clark, D. G. (2006) Recursion and aphasic sentence comprehension. Brain and Language 99, 114-115.
Folstein, M. F., Folstein, S. E., McHugh, P. R. (1975) "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician". Journal of psychiatric research, 12/3, 189-98.
Hauser, M. D., Chomsky, N., Fitch, W. T. (2002) The faculty of language: what is it, who has it, and how did it evolve?. Science, 298, 1569–1579.
Rosen WG, Mohs RC, Davis KL. A new rating scale for Alzheimer's disease. Am J Psychiatry. 1984 Nov;141(11):1356-64
Stark, J. (1994) Ela: Everyday Life Activities - Photo Series [Paperback]. Psychology Press
World Health Organization (1993), The ICD-10 Classification of Mental and Behavioural Disorders: Diagnostic Criteria for Research. WHO, Geneva.