Higher order categorization in aphasia

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Résumé

Cette recherche met en avant le fonctionnement des mécanismes de catégorisation de haut niveau dans l'aphasie. Le logiciel utilisé permet d'observer les stratégies de catégorisation de manière graduelle : une tâche de catégorisation libre, suivie d'une tâche induite, et pour finir, une tâche de catégorisation guidée. Les stimuli sont composés de phrases partageant des traits linguistiques communs aux niveaux : sémantique, prosodique et syntaxique. Les expériences ont été menées auprès d'une population de trente sujets sains et vingt et un patients aphasiques. Les résultats exposés ici sont issus de la première expérience de catégorisation libre. Prenant en considération les aspects linguistiques et cognitifs, nous mettons l'emphase sur l'analyse de la composante sémantique, celle-ci étant le critère choisi par excellence par la majorité de participants. Ce travail de recherche étant en cours de préparation, seuls les résultats préliminaires seront présentés.

Abstract This investigation assesses higher-order auditory categorisation mechanisms in aphasia. A computer program interface was used to observe categorisation in a graded manner, ranging from unrestricted to guided tasks. The stimuli consisted of sentences displaying multi-dimensional commonalities across three linguistic components: semantics, prosody and syntax. The experiments were conducted on a population of thirty healthy controls and twenty one aphasic patients. The results for the first free-sorting experiment are discussed in terms of linguistic and cognitive resources. An explicit emphasis is devoted to the interpretation of semantics as it proved to be the reference criterion employed by healthy and pathological participants in the unrestricted tasks. This is ongoing research and only preliminary results are presented.

Mots-clés : aphasie, catégorisation, cognition, haut niveau, compréhension orale.

Keywords: aphasia, categorisation, cognition, higher order, auditory comprehension

1 Introduction

One of the core issues in human cognition is how knowledge about the world is represented and organised in the mind. An influential tendency in cognitive psychology suggests that this process is driven by mechanisms of categorisation – the processing of objects/concepts in terms of underlying abstract representations or categories (Harnad, 2005). Classically, categorisation was conceived in terms of a taxonomic structure in which category membership is dictated by a set of defining features (Bruner, Goodnow & Austin, 1956). This approach was further extended through the Binary Model of concept structure in which characteristic features were added to account for those superficial/incidental features that reinforce category membership but do not determine it (Smith, Shoben & Rips, 1974).

Contrary to these theoretical approaches, two alternative models were developed in the late 1960s which proposed a hierarchical structure in categorisation: Collins and Quillian's (1969) and Rosch's (1975). Whilst the former advocated a model which consisted of visual representations of conceptual maps in memory (semantic networks), the prototype theory assumed categories to be based upon a graded structure in relation to a central mental average or prototype (Rosch, 1975). The prototype theory posits that category membership is determined by the similarity of members with respect to this central exemplar.

Recent studies on categorisation also attempt to ground it to contextual factors such as situation and action (Barsalou, 2005). Granting context an essential role in the categorisation process, Barsalou's research emphasizes flexibility at the core of categorisation. The importance placed on similarity to a mental average is reduced with more emphasis placed on situational information.

1.1 Comprehension and Categorisation in aphasia

In psycholinguistics, extensive research has attempted to understand the nature of domain-specific comprehension disorders in aphasia through analyses of lexical knowledge and semantic impairments (Caramazza & Mahon, 2003; Goodglass & Baker, 1976; Zurif, et al., 1974) .

In cognitive psychology, categorisation processes in language pathology have also been undertaken at the lexical level investigating both rule-based processes and prototypic strategies (Grober et al., 1980; Grossman et al, 2003; Koening et al., 2005; Roberson et al., 1999). The general results argue for a massive impairment of rule-based categorisation. In aphasia, it appears that whilst individuals with anterior aphasia show accurate albeit effortful categorisation, individuals with posterior aphasia display ill defined representation of categories. This inability has been attributed to a loss of prototypes with reliance on superficial characteristic features, often dependent on idiosyncrasy as opposed to the specific semantic elements of the tests (Grober et al., 1980).

1.2 The Prototype Theory as a Theoretical framework

The prototype theory stands as a landmark reference for categorisation in the field of Cognitive Psychology, both in normal and pathological functioning. In an array of investigations which analyse lower order categorisation, a wealth of empirical research exists to strongly support the theoretical premises. In his Idealized Cognitive Model (ICM) Lakoff (1987) puts forward a typology of prototypes. His examples illustrate different levels of mental representations[1] supporting the core theoretical premises of the prototype theory. As for the application of the prototype theory to language pathology, empirical research has shown the impact of prototypic versus non prototypic categorization in aphasia (Grober *et al.*, 1980; Kiran and Thomson, 2003) and in psychiatric diseases (Cantor et. al., 1980)[2].

Notwithstanding the aforementioned empirical findings, the ability of the prototype theory to neatly model higher-order categorisation behaviour, particularly when dealing with abstract notions, is not so salient. This is a result of the fact that these manifest extremely flexible boundaries as opposed to concrete lower order categories (Hampton, 1981). Likewise, some limitations have been raised with regards to one of the core assumption of the prototype theory; that is, that similarity lies at the core of the categorization process (Smith & Sloman, 1994). It has also been argued that this notion has no grounding for concepts (Roberson, 1999) and that abstract relationships are better defined in terms of rules (Pothos, 2005). Rule processing would follow a more restricted relationship amongst subsets of relevant features as opposed to a more flexible similarity operation in which more or less all relevant features would be considered. Abstract knowledge, as stated by Pothos (2005), is developed through explicit rules and not generated from associative similarity operations.

This paper contests that rule based processes along with the theoretical findings of the prototype theory must be incorporated to establish a rigorous theoretical framework for the analysis of higher-order categorisation. It evaluates linguistic categorisation at three levels: semantics, syntax and prosody and predicts rule-based processes for categorising according to semantic information.

The stimuli used were constructed along sentences in order to provide some contextual information. At this level, the stimuli used intended to avoid superficial similarity cues across sentences. In categorising by meaning, sentences have been constructed to only portray systematic relationships in terms of three abstract notions; that is, a sort of relationship that is not defined in terms of superficial attributes.

The research presented in this paper employs an innovative categorisation tool which allows both linguistic and cognitive processes to be monitored. Through observation of the strategies deployed, conclusions are made regarding to what extent conceptual knowledge disruption, comprehension deficits and other and non-linguistic factors affect these operations.

2 Methods

2.1 Participants

Thirty normal participants (age range 45 to 85 years, M= 62,66, S.D.= 7,31) were tested to validate the stimuli and ensure that no unpredicted or overseen associations existed between different sentences.

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[1] I.e. *typical cases, ideal cases, anti-ideal cases.*

[2] See page 2 for more detailed information on this topic.

Twenty-one aphasic patients participated in this study (age range 34 to 85, M= 59,43, S.D.= 12,06). They were recruited from the Speech and Language Therapy Unit at the Hospital Bellvitge, Barcelona, Spain and all provided informed consent for the study. Pretesting measures were administered to the participants to assess their auditory comprehension and deficits in working memory. This diagnosis was undertaken by a professional neurologist (mostly with CT scans) and by the local Speech and Language Therapist, using two standardised batteries: adapted versions to Spanish of the Protocole Montréal-Toulouse (Buenos Aires); and the Token Test.

Tables 1 and 2 are summaries of the demographic and pre-experimental testing data for each aphasic participant respectively.

PATIENT	APHASIA TYPE	G.I.	A.W.C.	A.S.C.	V.W.C.	V.S.C.
C.P.	ANOMIC	1	1	0,75	0,75	0,75
N.M.	ANOMIC	1	1	0,75	0,75	1
J.CEB.	ANOMIC	0,75	1	0,75	0,75	1
I.G.	ANOMIC	1	1	0,75	0,5	0,75
L.F.	CONDUCTION	0,75	1	0,75	0,75	0,75
J.M.C.	CONDUCTION	1	1	1	0,5	1
F.L.	BROCA	0,75	1	0,25	0,25	0,75
F.M.	BROCA	1	1	0,5	0,25	0,75
F.G.	BROCA	0,75	0,75	0,75	0,75	1
J.P	BROCA	0,75	1	0,5	0,75	0,5
F.N.	BROCA	0,75	0,75	0,5	0,75	0,75
S.V.	BROCA	0,75	1	0,5	0,5	0,5
A.C.	TRANSCORT-MOT	0,75	0,75	0,5	0,75	0,75
M.R.	TRANSCORT-SENSO	0,75	0,75	0,5	0,25	0,75
P.F.	TRANSCORT-SENSO	0,75	0,75	0,25	0,5	0,75
J.C. (1)	TRANSCORT-SENSO	0,75	0,5	0,5	0,25	0,5
J.C. (2)	TRANSCORT-SENSO	0,75	1	0,5	0,5	0,5
J.N. (1)	WERNICKE	0,25	0,5	0,25	0,25	0,5
J.N. (2)	WERNICKE	0,5	0,75	0,25	0,25	0,75
J.S.	WERNICKE	0,25	0,25	0,25	0,25	0,25
J.G. (1)	NON-CLASSED	0,75	0,75	0,5	0,5	0,75
J.G. (2)	NON_CLAS	0,75	0,75	0,5	0,75	0,75
J.G. (3)	NON_CLAS	0,75	0,75	0,5	0,75	0,75
C.F.	BROCA	1	1	1	0,75	1
M.G.	ANOMIC	1	1	0,5	0,75	1

G.I.: Guided Interview
A.W.C.: Auditory Word Comprehension
A.S.C.: Auditory sentence comprehension
V.W.C.: Visual Word Comprehension
V.S.C.: Visual Sentence Comprehension
Values:
0,25 = Severe
0,50 = Moderate
0,75 = Mild
1 = No Deficit

Table 1: Results of Protocole Montréal Toulouse /Buenos Aires- Barcelona.

PATIENT	APHASIA TYPE	W.M.	T.S.O.	T.T.	ETIOLOGY
C.P.	ANOMIC	5	17	28	Traumatism/left parietal
N.M.	ANOMIC	5	10	34	Meningiome/ left atrio ventricular
J.CEB.	ANOMIC	2	6	23,5	Ictus/Middle left cerebral artery
I.G.	ANOMIC	5	4	24,5	Ictus/Middle left cerebral artery
L.F.	CONDUCTION	1	8	20	Multiform Gliobast/left temporoparietal
J.M.C.	CONDUCTION	3	7	24	Ictus/Middle left cerebral artery
F.L.	BROCA	0	8	8,5	Ictus/Middle left cerebral artery
F.M.	BROCA	3	9	23,5	Ictus/Middle left cerebral artery
F.G.	BROCA	4	8	20	Ictus /frontal temporal
J.P	BROCA	3	15	22	Ictus /frontal temporal
F.N.	BROCA	0	24	23	Ictus /frontal temporal
S.V.	BROCA	3	7	28	Ictus /frontal temporal
A.C.	TRANSCORT-MOT	3	5	20	Ictus/ Posterior left cerebral artery
M.R.	TRANSCORT-SENSO	5	4	12	Ictus/Middle left cerebral artery
P.F.	TRANSCORT-SENSO	2	4	13	Ictus/Middle left cerebral artery
J.C.	TRANSCORT-SENSO	4	3	15	Thrombose/left silvian territory
J.C.	TRANSCORT-SENSO	5	15	17	Thrombose/left silvian territory
J.N.	WERNICKE	0	2	12	Ictus/Middle left cerebral artery
J.N.	WERNICKE	1	14	18	Ictus/Middle left cerebral artery
J.S.	WERNICKE	2	6	6,5	Ictus/Middle left cerebral artery
J.G.	NON-CLASSED	3	4	25	Ictus/Middle left cerebral artery
J.G.	NON_CLAS	4	16	27	Ictus/Middle left cerebral artery
J.G.	NON_CLAS	4	18	27	Ictus/Middle left cerebral artery
C.F.	BROCA	6		30	Ictus/Middle left cerebral artery
M.G.	ANOMIC	3	10	22	Haematoma/left parietal temporal

W.M.: Working Memory
T.S.O.: Time Since Onset
T.T.: Token Test

Table 2: Complementary tests, neurological information.

2.2 Materials

Aiming to provide contextual information, the test employed sentences instead of isolated words. In total sixteen sentences were constructed with highly frequent vocabulary (see appendices 1 and 2). They were recorded by a trained male speaker at a normal rate.

In each sentence, three linguistic components were assessed: syntax, semantics and prosody. They were constructed as follows: three semantic abstract notions (education, travelling, fear) and four distracting semantically themes; two prosodic marks (marked and unmarked); and two syntactic patterns (simple and complex).

Table 3 shows the four sentences constructed for the semantic notion *travelling,* which were built on the two syntactic patterns and portrayed the two prosodic marks:

	Luis va de vacaciones a las playas de Andalucía cada verano	Syntactic Pattern 1
Marked prosody	**A Elisa le gusta ir de viaje solamente en su avión privado**	Syntactic Pattern 1
Marked prosody	**Andrea sueña con poder ir a Jamaica pero es tan pobre**	Syntactic Pattern 2
	Ingrid va a Marruecos con nosotros pero sólo por unos días	Syntactic Pattern 2

Table 3: Example of sentences constructed for the semantic notion *travelling.*

Semantics: The sentences were linked together by three abstract notions: education, travelling and fear. There were no identical lexical items across different sentences. This forced semantic processing beyond the lexical level in the case that participants wanted to categorise the sentences around the three semantic concepts manipulated. Participants were required to access the abstract notions that linked sentences together in order to successfully categorise at this level. Four semantically distracting sentences were also included. Theses were introduced to assess the participants' capacity to inhibit them when categorising semantically according to our predictions. They will be interpreted in terms of intrusive elements for the semantic categories we have anticipated. For example, the presence of a sentence referring to Monica being a liar (semantic distracter 4) in a category grouping the sentences related to the notion travelling, would be consider as an intrusive element for this category.

Syntax: The sentences were constructed along two syntactic patterns: simple assertive and complex adversative coordinate. The length of each sentence in time was also controlled (range 3.27 - 4.10 sec, M= 3.614 sec.) and in syllables (range 8-12 syllables, M= 10 syllables) to ensure that complex structures were not longer than simple patterns and that this would not serve as criteria to differentiate sentences along this level. A syntactic rule, and not length criteria, would form the basis for categorisation.

Prosody: Two prosodic levels of emphasis were controlled in the experiments: marked and unmarked, that is, either the sentences were given a special intonation emphasis or they were pronounced in the most neutral way possible by the trained speaker.

The sentences were built in such a way as to portray multi-dimensional similarities across these three levels. This created the opportunity for subjects to discern parallel commonalities between semantic, syntactic and prosodic themes. As a result, it was possible to observe which linguistic level was more prominent for each subject in the unrestricted categorisation task.

2.3 Procedure

The participants listened to the sentences above described. The task consisted of grouping them together according to what they had in common. The possibility existed for the participants to leave any sentence isolated, that is, outside of any categories, if they considered that it did not share any common attribute with any of the other groups formed. There was no temporal constraint imposed and the participants were able to listen to the stimuli as often as they felt necessary. The participants undertook the test via a computer program interface called TCL - Lab 0.25 (Gaillard, 2008). A pre-test was designed with unrelated auditory material to provide training and ensure participants' capacity to perform the task.

The computer program interface used records fine-grained temporal and procedural data. The analysis of these data and its impact on the final results is part of our ongoing research, as it may shed light on possible strategic behaviour both for patients and healthy participants in a categorization task of this nature. Future publications will focus on these results.

3 Results

3.1 Data analysis

The quantitative results for control participants are displayed through the statistical representational tool of proximity trees. See appendix 2 for results of healthy participants.

Given the heterogeneity and reduced number of our aphasic population, a different method was employed for the analysis of their categorisations. Scores were adjudicated to each of the linguistic themes/patterns predicted by this research. Both, the grouping together with and without intrusive elements were considered. The following table summarises the scores for semantic, syntactic and prosodic categories, both with and without intrusive elements.

Semantic Categories Score for 'correct' items
2 items = 0,50
3 items = 0,75
4 items = 1

Prosodic/Syntactic Categories Score for 'correct' items
2-3 items = 0,25
4-5 items = 0,50
6-7 items = 0,75
8 items = 1

Intrusive items/ in semantic categories		
Number of correct items	Computation	Score for each intrusive item
4	1/4	0,25
3	1/3	0,33
2	1/2	0,5

Intrusive items/ in prosodic & syntactic categories		
Number of correct items	Computation	Score for each intrusive item
8	1/8	0,125
7	1/7	0,142
6	1/6	0,166
5	1/5	0,2
4	1/4	0,25
3	1/3	0,33
2	1/2	0,5

Table 4. Summary of scores for linguistic categories.

3.2 Results for the Free-Sorting task

The high indexes in the tree displayed in appendix 2 confirm the solidity of these results. The predominant tendency of categorisation based on the semantic themes is revealed by the three solid nodes that contain the items related to the three semantic abstract notions predicted by this test. The following table shows the chosen dominant criterion for categorisation, both for healthy participants and aphasic patients:

Scores dominants sujet * TYPE Crosstabulation

Count

		TYPE		
		PATIENT	HEALTHY	Total
DOMINANT CRITERIA	NO DOMINANT CRITERIA	1	0	1
	PROSODY	1	1	2
	PROSODY+SYNTAX	2	0	2
	SEMANTICS	20	27	47
	SEMANTICS+PROSODY	1	1	2
	ALL	0	1	1
Total		25	30	55

Table 5. Dominant Scores for Categorisations.

An independent sample T-Test was conducted to compare the scores obtained from aphasic patients, both considering the presence and absence of intrusive elements. There was a significant difference in the scores for semantic scores without intrusive elements for patients (M=0,62, S.D.= 0,322) and healthy participants (M= 0,91; S.D.= 0,19); t(52)= 4,17, p=0,000. This difference was also significant for the scores with intrusive elements for patients (M=0,522; S.D.=0,37) and healthy participants (M=0,90; S.D. =0,21); t(52)=4,60, p=0,000.

Further analysis evaluated the impact of other variables, such as age, time since onset, working memory capacity, comprehension level (both for Token Test and Protocole Montréal Toulouse/Buenos Aires-Barcelona results) and educational level on the semantic performance of patients. Linear regressions were conducted to assess the effect of age, comprehension level, working memory span and time since onset. Results proved significant only for comprehension level.

A linear regression revealed that Token Test scores was a highly significant predictor of semantic scores both for scores without intrusive items (β = 0,30; p = 0,00) and with them (β = 0,36; p = 0,00), accounting for 64% of the variance in semantic scores. Similarly, the scores obtained from the Protocole Montréal Toulouse/Buenos Aires-Barcelona significantly predicted semantic scores without intrusive elements (β = 1,14; p = 0,02) and with them (β = 1,63; p = 0,00), accounting for 59% and 72% of the variance in semantic scores respectively.

A one-way ANOVA was conducted to compare the effect of level of education on semantic scores in elementary school level, high school level and university level conditions. Results showed this factor had a strong impact on semantic scores with and without intrusive items, at the $p<0.05$ level for the three conditions. With intrusive items: [F(2,2)=8,46, p=0,001]; and without them: [F(2,2)=13,35, p=0,000).

3.3 General discussion

One clear conclusion from these results is the important role that semantics played in the free-sorting task. Taken apart the five patients and three healthy participants who exhibited mixed, prosodic or no clear criterion, the rest of the participants visibly privileged semantics for their categories made. The results put forward by the T-Test as well as by the proximity tree for healthy subject confirm that the free sorting task, having semantics as the outstanding criterion, is perfectly achievable for healthy participants, but not necessarily by all patients. This comes to validate the sentences constructed for this experiment, as healthy participants prominently managed to take notice of the semantic themes predicted by the experiment[3].

Patients J.C. and P.F. (Transcortical Sensory aphasias) and J.G[4]. (non classified), chose either prosodic or mixed criteria for their categories, whereas patient A.C. (Transcortical Motor aphasia) was unable to complete the task (see appendix 4 for general semantic scores). It is interesting to notice that, albeit their well known severe comprehension deficits, Wernicke's aphasias (J.N. & J.S.) still managed to portray a semantic categorisation as opposed to the two Transcortical Sensory aphasias aforementioned. This is consistent with the idea that they are able to process semantic information to a certain level, as previously put forward in the literature concerning automatic semantic processes (Friederici, 1983). It seems then that Transcortical Sensory aphasias would be the aphasic profile with the poorest performance for this sort of task. With the exception of M.R[5]., none of these patients was able to use semantics as an evident criterion for their categories. Further research on a larger population would be necessary to confirm this assumption and disentangle the specific factors affecting these patients in this type of task.

Taken together, these results suggest that a categorisation task of this nature is highly dependent on comprehension. Accordingly, low comprehension aphasics are significantly more impaired than high comprehension aphasics in a higher order categorisation task, as confirmed by scores obtained from both standardised batteries used. Hence, an orally presented categorisation task of this nature appears to offer an alternative option in the assessment of semantic disorders.

Along with the comprehension deficits, the educational level also proved essential for a completion of this experiment following semantic criteria. In our results, the higher the educational level, the better the semantic categorisation[6]. It seems plausible to predict that the mental and linguistic capacities enhanced by education has an effect on both, patients and healthy participants' capacity to use semantic knowledge to categorise in a higher order task. Though it is beyond the scope of this paper to attempt to unravel the intricacies of linguistic relativity and determinism; that is, the convoluted relationship between language and thought[7], a broad interpretation of these results seem to support the idea that these two are highly intertwined.

[3] Similar results were obtained from healthy participants in induced and guided tests at the prosodic and syntactic level. These results are being analysed and will be presented in future publications.

[4] Data obtained from two different sessions.

[5] Possibly due to patient's M.R. University studies compensated her performance for this test, which is not surprising after the significant results this variable showed on the overall performance of participants over semantic scores.

[6] As it was mentioned in the section concerning the materials, it is interesting to remind here that the demands for a semantic categorisation in this experiment require, necessarily, some higher level abstract thinking. Given that there are no superficial clues (such as lexical similarity) linking the items together at this level, the participant must necessarily find an abstract notion, 'a summary representation' to be able to find the commonalities across the items. For example, to be able to group sentences together corresponding to the semantic field 'education', the participant must access some level of abstraction or prototypic mental idea of this notion, keep it temporarily in storage and find other items that also refers to the same idea.

[7] The old Whorf-Sapir debate currently revived by recent research on embodied cognition (see Slobin, 1996)

As for the working memory capacities, our results surprisingly suggest that they manifest no significant effect for this task. Albeit commonly considered as a cognitive skill affecting comprehension, the relationship between working memory resources and comprehension deficits remains controversial[8]. These results emerge to support the idea that working memory capacity and language comprehension disorders are, at least partially, not interdependent.

In our experiment, participants must temporarily access and hold in memory the criteria chosen which, given the length in time of the test[9], exceeds working memory capacity. Consequently, we assume that memory demands for this test are probably situated somewhere between a long term storage and a working memory buffer (Baddeley, 1996). Taking this fact into consideration, as well as the possibility that subjects have to listen again any item whenever they desire to, no conclusion is offered yet concerning this variable.

As for the theoretical premises above stated, these results provide further empirical evidence that higher order rule-based semantic processes are impaired in aphasia. The level of impairment in directly related to the comprehension deficits. Overall, aphasic individuals with low comprehension showed the most ill-defined categories. That is, they had the poorest semantic categories both in terms of number of correct items/intrusive items and in terms of mixed criteria. This could be interpreted as either a lack of access to a mental 'summary' or prototype of semantic fields, or as a loss or degradation of the field itself. Given the present state of the research and the complexity of the data, it is not possible yet to offer a clear conclusion concerning the exact level of disruption where patients fail. Future research aims at disentangling these aspects.

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[8] As argued by Caplan, Hildebrant, 1988, with respect to agrammatic comprehension deficits.

[9] We are currently interpreting the data concerning temporal strategies used for categorisation, as recorded by the computer program we used. Patients tend to take from 15 to 45 minutes to complete the first test.

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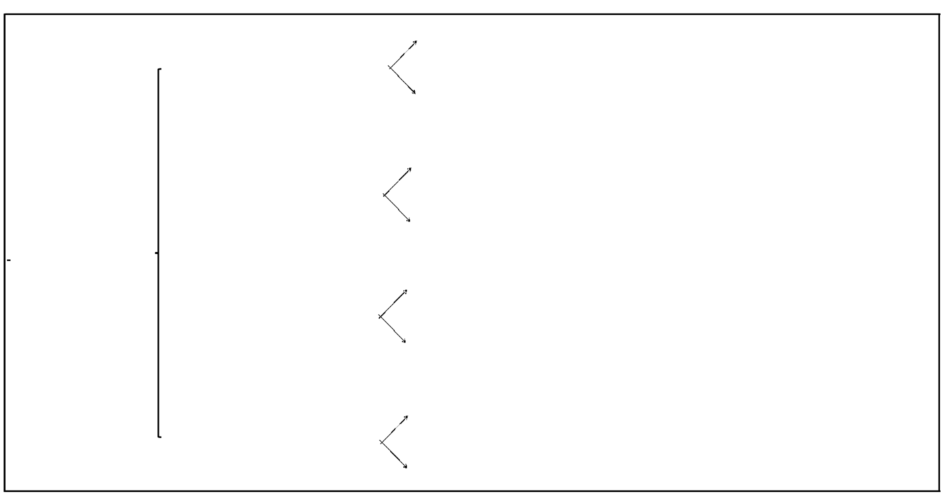
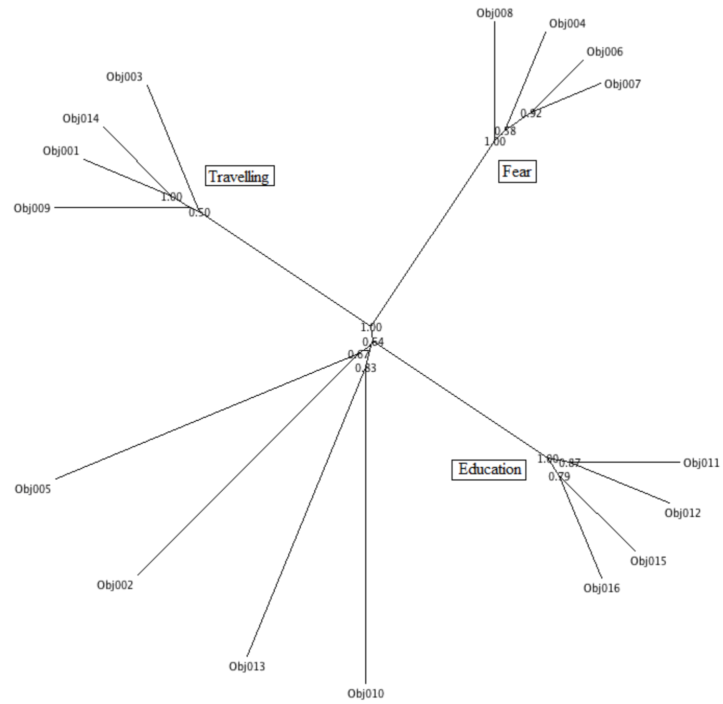
Appendices



Appendix 1. Sentences constructed along syntactic pattern one.



Appendix 2. Proximity tree for healthy subjects

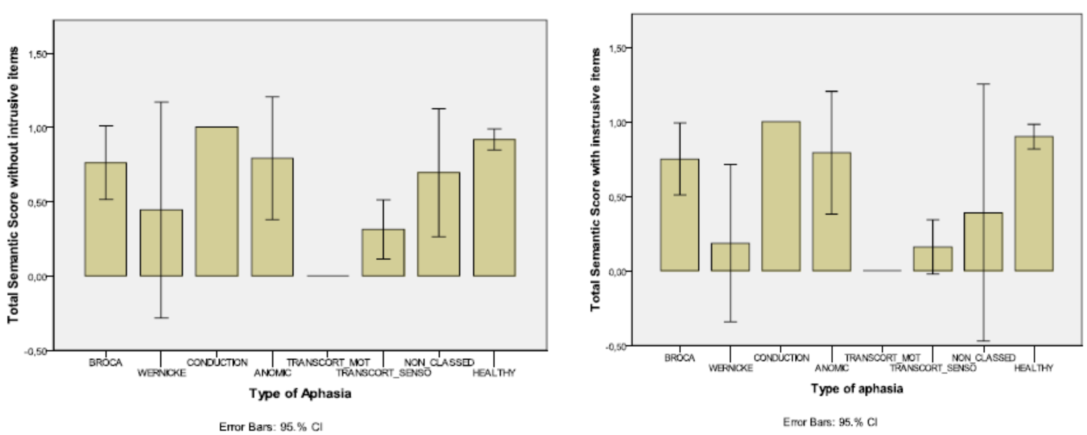


Figure 4. Mean of semantic scores for all participants