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**Intonational patterns and
comprehension in Broca's aphasia**

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MA Thesis

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Bellaterra, August 2010

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ACKNOWLEDGMENTS

This study would have not been possible without the support of many people. I am especially grateful to my supervisor, Prof. Anna Gavarró, for her guidance and persistent assistance. This dissertation undoubtedly benefited from her deep knowledge, valuable suggestions and meticulous correction.

I would also like to acknowledge Prof. Eulàlia Bonet for the shared phonological expertise that contributed to refine the theoretical description of phonology and the prosodic analysis of Catalan utterances.

Thanks are also due to the Servei d'Estadística de la UAB and, specially, to the statistician Anna Espinal, for her contribution to the analysis and interpretation of data.

I am deeply thankful to the Associació Sant Pau de Trastorns de la Comunicació (Barcelona) and, especially, to José Luis Cardona, whose help and dedication were decisive in finding the aphasic subjects. I also wish to express my gratitude to Silvia Martínez-Ferreiro for introducing me to the speech disorders association and offering her help.

Special thanks should be given to the aphasic volunteers that participated in the experiment and to their families, for adapting their schedule and dedicating their time to us. I would also like to thank the control subjects for their participation and time, and also express my thanks to those who helped me to contact them. Needless to say, it would have been impossible to carry out the experimental tasks without their help.

I would also like to acknowledge all the individuals who assisted me during the project. I specially wish to thank those friends that participated directly in the study: Eduard Artés, who read the tokens, and Eduard Mateu, who helped me to solve technical problems. Finally, my parents also deserve some words of acknowledgement for their wonderful support and assistance.

ABSTRACT

Agrammatic comprehension is a relatively recent topic in studies that focus on Broca's aphasia, which has been traditionally considered a mainly "expressive" disturbance. It was not until the 1970s, when some researchers (among others, Caramazza & Zurif, 1976 and Schwartz, Saffran & Marin, 1980) claimed that a comprehension disruption accompanied the production impairment. A controversial discussion on the nature of the impairment began, and Grodzinsky (1984a, 1986) argued that it was partial and affected some syntactic operations. Later, he developed a theoretical description of the disruption, the Trace-Deletion Hypothesis (1990, 1995a, 2000b), embedded in the generativist framework. According to the Trace-Deletion hypothesis, the nature of the impairment is exclusively syntactic and it is assumed that aphasic individuals do not present problems in other levels of grammatical knowledge, such as phonology. However, there is an experimental gap concerning the phonological skills of Broca's aphasic individuals, especially in the Romance languages. Therefore, the goal of the present study is to determine whether the deficit is syntactic in nature and that aphasic individuals preserve their phonological abilities intact. This has important implications, since it contributes to achieving a more complete characterization of agrammatic comprehension and reexamines the assumptions on which the Trace-Deletion hypothesis rests. Here, an experimental task is designed and carried out with six Broca's aphasic subjects and six control subjects, in order to find out whether aphasics preserve their phonological skills. The participants were asked to listen to pairs of Catalan utterances and to say whether the pairs sounded different or the same. The pairs combined four different intonational contours (yes-no questions, neutral declaratives, contrastive focus and topics). Both control and aphasic subjects performed above chance on all conditions, which confirms that Broca's aphasic patients' impairment occurs elsewhere in the grammar. The results of the present study establish that Catalan aphasic individuals' comprehension does not result from a phonological impairment.

1. Theoretical background and goals

1.1. Agrammatic comprehension

Since the nineteenth century, and after the study of Paul Pierre Broca (1861), Broca's area was thought to be responsible for speech production. From that time on, studies on Broca's aphasia have focused on the effortful and telegraphic speech of patients. In fact, Broca's aphasia is commonly known as nonfluent, expressive or motor aphasia, names which refer to the production deficit. Therefore, the classification of the aphasias is largely the result of a channel-based model (Wernicke, 1875 and Geschwind, 1970) in which Broca's area was considered to be the neural centre for speech production, and independent of speech comprehension, which was supposed to rely on Wernicke's area. In Figure 1, the three main language centres in the left hemisphere of a human brain are represented as Wernicke (1875) conceived them: B stands for Broca's area (speech production centre), W for Wernicke's area (speech comprehension centre), and A for the arcuate fasciculus (a link between Broca's and Wernicke's area).

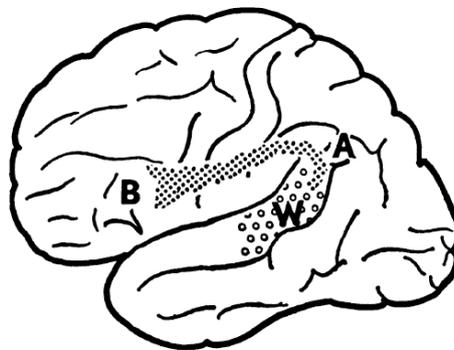


FIGURE 1. Lateral surface of the left hemisphere of a human brain. Source: Geschwind, 1970.

An *expressive* aphasia would thus be understood to result from damage in Broca's area, which was described as an effortful, telegraphic and poorly articulated speech. In addition, researchers observed that Broca's aphasics were unable to produce grammatical sentences, even though they retained other abilities like comprehension of spoken language. In contrast, a *receptive* aphasia would result from damage in Wernicke's region. This kind of aphasia was described as a fluent, effortless but nonsense speech. Patients showed an impaired comprehension of both spoken and written language, and they were observed to confuse words and sounds (paraphasias).

However, during the 1970s, some studies claimed that there was a comprehension deficit in Broca's aphasia, besides the typical disturbance of production that had been previously reported (Goodglass, 1968; Zurif, Caramazza & Meyerson, 1972; Zurif, Caramazza, Myerson & Galvin, 1974; Caramazza & Zurif, 1976 and Zurif & Caramazza, 1976). Underlying these studies is the fact that the apparent disassociation between aphasic comprehension and expressive abilities would indicate that, indeed, Broca's aphasia would be the result of a disturbance of expressive performance system. Yet, it was observed that Broca's aphasics did not preserve their comprehension abilities intact, and this fact led to the conclusion that the deficit was syntactic in nature. In fact, several experiments were conducted in order to test how aphasics perform in tasks in which comprehension depends on syntactic features of the utterances, and it turned out that aphasics' comprehension was compromised. In Caramazza and Zurif (1976), Broca's aphasics were asked to choose the picture they thought to capture the meaning of the sentence read by the experimenter (*sentence-picture matching task*). The results confirmed that aphasic comprehension was impaired. Patients were able to interpret sentences which presented the canonical order in English, SVO, as they would interpret active sentences and subject relative clauses, as in example (1a), and even semantically nonreversible sentences which did not present the canonical order in English (passive sentences and object relative clauses), like sentence (1b). However, they were not able to decode sentences in which syntactic properties played a crucial role in interpretation of reversible sentences like (1c):

- (1) a. The man is reading a yellow book.
- b. The book that the girl is reading is yellow.
- c. The girl that the boy is hitting is tall.

These results lead to the conclusion that the deficit resulting from damage in Broca's area affects syntactic procedures which underlie different language modalities, including both comprehension and production skills, and that this deficit is often compensated by heuristic strategies. Hence, the traditional account of Broca's aphasia was rejected and the channel-based model by Wernicke (1875) was replaced by a new model, in which Broca's area was considered responsible for syntactic processing. Zurif (1980) postulated the so-called *overarching agrammatism*, this is, a parallel deficit that affects both production and comprehension.

Later, other studies rejected the idea that Broca's aphasia consists of a complete loss of syntax and proposed a new account based on some experimental evidence (Schwartz, Saffran & Marin, 1980; Linebarger, Saffran & Schwartz, 1983a, 1983b; Schwartz, Linebarger, Saffran & Pate, 1987). Although results showed that there was an evident deficit in aphasics' comprehension, researchers postulated that Broca's aphasics impairment is due to a mapping deficit. That is, patients are not able to map syntactic positions on semantic roles. In Schwartz, Saffran & Marin (1980), aphasics' comprehension of active and passive sentences was tested. Even though experimenters expected them to interpret utterances applying consistently a fixed word order (SVO), it turned out that most of the subjects failed in comprehending both active and passive sentences. In addition, aphasics' grammatical knowledge was tested through a grammaticality judgement task in a later study (Linebarger, Saffran & Schwartz, 1983b). Since aphasic subjects succeeded in recognizing ungrammatical utterances, these authors thought that is confirmed that Broca's aphasics retain their grammatical knowledge, with the deficit affecting mapping processes.

Soon, theoretical studies on aphasia focused on the nature of the linguistic impairment (syntactic according to Heilman & Scholes, 1976; Ansell & Flowers, 1982a,b; and Caplan & Futter, 1986; phonological according to Kean, 1977) instead of the different language modalities (production, comprehension, writing, reading...) it would affect. Caplan & Futter (1986) took into account different analyses that were reported by previous studies (Caramazza & Zurif, 1976; Schwartz, Saffran & Marin, 1980) and conducted an experiment in order to find out whether the impairment of an aphasic patient was due to loss of syntax (as Caramazza & Zurif (1986) claimed) or to a syntacticosemantic mapping deficit (as Schwartz, Saffran & Marin (1980) claimed). These last-named authors used a large variety of sentence types and looked at how different syntactic structures influenced aphasics' performance and, even though subject's performance depended on sentence structure, they concluded that the patient was not able to interpret the utterances relying on their syntactic properties. Yet, since several regularities were observed in interpreting sentences, these researchers thought the patient to use strategies of some kind which would aid in the utterances' comprehension. Hence, they 1) postulated an agrammatic comprehension which consisted of a severe loss of syntax and claimed that their patient only retained very

simple syntactic structure and 2) rejected the mapping hypothesis (Schwartz, Saffran & Marin, 1980), given that the aphasic was able to map theta-roles onto syntactic constituents that she could recognize (nouns and verbs). According to their analysis, the strategy used in order to assign thematic roles depends on the linear order of words and not on syntactic structure.

Grodzinsky (1984a, 1986, 1990, 1995a; Grodzinsky & al., 1999) revised the data reported in previous studies and, besides reviewing their experimental designs, highlighted the fact that most of those studies had reported patients' difficulties in comprehending some specific sentence types (even Schwartz, Saffran & Marin's study (1980), although without taking into account structural properties of the tested sentences). Hence, the last-named study focused on the contrasts among syntactic structures and the comprehension patterns related to them; such contrasts were observed between active and passive sentences and between subject- and object relative clauses. Broca's aphasic patients performed above chance in tasks that required comprehension of active sentences and subject relative clauses, but at chance when they tried to interpret reversible passive sentences and object relative clauses. Sentences (2a, b) have been taken from Schwartz, Saffran & Marin's study (1980) and exemplify the first distinction concerning active and passive sentences. While active sentences like (2a) are interpreted correctly by Broca's aphasics, patients perform as guessing in tasks in which passive sentences like (2b) are involved:

- (2) a. The man kisses the woman.
- b. The man is kissed by the woman.

Similarly, they are able to interpret subject relative sentences like (3a), but not object relative sentences like example (3b), from Caramazza & Zurif (1976):

- (3) a. The cat that is biting the dog is black.
- b. The cat that the dog is biting is black.

These differences in performance depending on syntactic structures led to the conclusion that agrammatic comprehension is a partial and restricted impairment concerning either syntactic structures or processes, instead of the complete loss of

syntax that some researchers postulated (among others: Caramazza & Zurif, 1976; Caplan & Futter, 1986). Accounts which denied the syntactic nature of the disturbance (Schwartz, Saffran & Marin, 1980) were ruled out because they were not sensitive to structural differences among tested utterances and could not predict performance of Broca's aphasic individuals (Grodzinsky, 1990).

Some researchers had introduced in their experiments sentences with different semantic properties, known as nonreversible and reversible sentences. The goal was to test patients' heuristic strategies and delimit the nature of the impairment. Nonreversible sentences are those like example (4a), in which thematic roles of agent (*the boy*) and theme (*the apple*) can hardly be switched—even though the string would be grammatical—given that it would evoke an awkward situation (an apple eating a boy, in this case). In contrast, reversible sentences, such as example (4b), do not impose this type of limitations, because the thematic roles can be reversed without invoking any awkward situation (in this case, a man hugging a woman or a woman hugging a man). In addition to this, the distinction between reversible and nonreversible utterances in Caramazza & Zurif's experiment (1976) emphasized the relevance of the syntactic structure in impaired comprehension, since the semantics of nonreversible sentences aid the subjects to choose the picture which did not evoke awkward situations. Given the example (4a), a Broca's aphasic patient would never point to the picture in which a red apple ate the girl, but instead to the correct interpretation. However, they would perform at chance in interpreting reversible sentences like (4b), in which syntactic properties are crucial.

(4) a. The apple that the boy is eating is red.

b. The man that the woman is hugging is happy.

In any case, Grodzinsky (1990) argued that the experimental design failed in this case, since patients would automatically ignore awkward pictures such as the one described above. Hence, the study did not really confirm the use of heuristic strategies by Broca's aphasics. However, Caramazza & Zurif (1976) noticed that some strategies—like heuristics—were used in order to compensate the impairment.

Another relevant contribution by Grodzinsky (1984; 2000a) was that of rejecting the so-

called overarching agrammatism (Zurif, 1980), which postulated a parallel deficit for production and comprehension. After reviewing data from previous studies and considering it together, in spite of individual variability (Grodzinsky et al., 1999; Drai & Grodzinsky, 2006), Grodzinsky was able to establish different comprehension and production patterns for Broca's aphasia and postulate two different hypotheses in order to describe and predict the disruption resulting from damage in Broca's area. Grodzinsky's deficit description (1986) consisted of two different accounts for production and comprehension impairment that involve different syntactic structures, the former was called the Tree-Pruning hypothesis and the latter, the Trace-Deletion hypothesis.

1.2. Framework

Since Grodzinsky (1986) has always argued that language deficits must be compared to normal language, his starting point is language theory which explains normal language structure. Examining the difference will show whether the impairment is due to a loss of specific structures or a disruption of specific processes. Broca's aphasics seem to fail in comprehending syntactic constructions which involve displaced constituents, hence, Grodzinsky postulates his hypothesis according to a current syntactic theory that explains transformational movements.

Grodzinsky postulated the Trace-Deletion hypothesis embedded in the Government-Binding Theory (hereafter, GB), which is a syntactic theory mainly developed by Noam Chomsky (1981) within the Transformational Grammar (Chomsky, 1965, hereafter, TG). The GB Theory consists of four levels of representation, two of them are relevant for the description of agrammatic comprehension: D(eep)-structure and S(urface)-structure. Each level has its domain to which some optional rules can be applied. Several constraints (principles) limit the application of these rules and determine the wellformedness of utterances. TG not only posits a hierarchical relationship among constituents which belong to different levels but also accounts for rules that explain dependencies among these constituents. Only one optional rule was postulated, Move-Alpha, in order to explain mapping from D-structure to S-structure and which permits constituents to move freely deleting or substituting categories. In passive sentences

Move-Alpha is triggered by properties of the passivized verb. A passivized verb loses the ability of assigning Case to its object and, as a consequence, the utterance violates the constraint known as the Case filter and the sentence is ill formed. Therefore, the determiner phrase occupying the object position needs to move to the subject position (example (5b)), which has a structural case assigned by the passivized verb. In example (5b), this position is represented as [e], which stands for an empty position, that is, not phonologically overt but structurally represented.

- (5) a. [e] was kissed [Mary]
b. [Mary]_i was kissed t_i

Some principles constrain the application of Move-Alpha, like the Projection Principle, which guarantees that lexical requirements are fulfilled. As an example, if a required constituent were deleted, it would violate the Projection Principle. This is the case of passivization (example (5a) and (5b)), where the determiner phrase (DP) in the object position is deleted after the constituent is moved to subject position. Hence, in order to account for this construction without violating the Projection Principle, it is necessary to postulate an abstract marker (a trace) left on the object position, which is thought to be structurally represented, yet phonologically empty. The trace must be connected to its antecedent by a common index that has important uses.

In fact, there is another principle, the Theta-criterion, which guarantees a proper assignment of theta-roles (agent, patient, theme, goal, etc.; Jackendoff, 1972): each argument can be associated with only one theta-role, and each theta-role can be assigned to one argument. If the criterion is not fulfilled, the utterance will be ungrammatical. This is the case of example (6), in which the transitive verb *send* requires an object to assign it a theta-role:

- (6) *Mary sends

The Theta-criterion also regulates which categories can be assigners of theta-roles, like verbs, and which categories can be assignees, like determiner phrases. In addition, every lexical entry has its theta-grid (Stowell, 1981), which regulates the number of theta-roles to assign to different syntactic positions and the identity of its assignees. As an

example, the verb *send* has the following theta-grid:

(7) send: <agent, theme>

The assignment of theta-roles (theta-marking) can be either direct or indirect. It is direct when the assignee to which a verb assigns a theta-role is phonologically overt, as in example (8), where the verb assigns the agent theta-role to the determiner phrase (DP) that occupies the subject position and a theme theta-role to the object.

(8) Mary sends a letter.
 | |
 agent theme

When the verb assigns a theta-role to a position which is not filled with a DP, but with a trace (structurally represented but not phonologically realized), the theta-role must be indirectly assigned to the antecedent of the trace through the index that both elements share. This is what happens in passive sentences, given that passivized verbs lose the ability to assign theta-roles to their subjects. Hence, the verb of a passive sentence will assign the theta-role to the trace that is occupying the object position and, through the index that the antecedent and the trace share, the antecedent will receive the thematic role. Sentence (9) exemplifies this:

(9) [A letter]_i is [_{VP} t'_i sent t_i]
 ↑ ↑
 └──────────┘
 theme

The subject of the passive (*the letter*) is base-generated and forced to move to the VP-internal subject position (VP-internal subject hypothesis (Kitiwaga, 1986; Kuroda, 1986; Koopman & Sportiche, 1988) and finally, it will rise to the subject position. The elements that share an index (the antecedent and both traces) form a syntactic chain, and its relationship is regulated by the Subjacency constraint, which guarantees that the constituent displaced has not been moved too far. Grodzinsky (2000b) exemplifies this with sentence (10), where the distance between the trace and its antecedent violates the

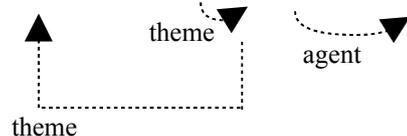
Subjacency constraint:

(10) *[which man]_i did Mary spread the rumour that she liked t_i

1.2.1. Syntactic analysis of relevant structures

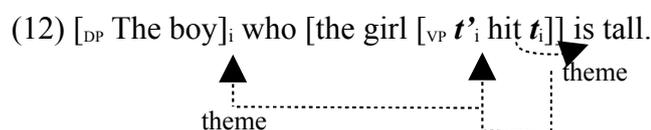
Given that Broca's aphasic patients have problems in comprehending sentences which involve movement operations, we will first account for nondisrupted language's representation of these utterances. We mentioned before the contrasts of performance depending on utterances with different structural properties. The first distinction that we highlighted was that Broca's aphasics perform above chance when they interpret reversible active sentences, but they guess in tasks where utterances are reversible passives. We saw in 1.2.1. that a passivized verb assigns a theta-role to its object, but not Case, and Case to its subject, but not a theta-role. This fact explains the triggering of the movement rule, since the utterance would be ungrammatical given the Case filter constraint. Due to the Projection Principle, a trace is left on the object position and receives a thematic role assigned by the verb. Then, through a common index that the displaced constituent and the trace share, the theta-role is indirectly assigned to the DP in the initial position. The theta-role assigned here is theme, while the agenthood is directly assigned to the postverbal constituent, a prepositional phrase (headed by the preposition *by*, which assigns the theta-role). Sentence (11) exemplifies this:

(11) [_{DP} The boy]_i was [_{t'}_i [_{VP} hit t_i]] by [the girl].



Other structures which involve transformational movement behave in a similar way, including reversible object relative clauses. In sentences of this kind, the object moves to the first position and receives its theta-role through the link established between the trace and its antecedent. Example (12) represents the S-structure of a sentence with a centre-embedded objective relative clause. The argument in the object position of the clause (*t_i*) moves first to the VP-internal subject position (*t'*) and then, to the head of the

relative clause, leaving a trace in both positions. The relative pronoun (who) links the displaced constituent with the relative clause. The antecedent and its traces are coindexed and form a syntactic chain, which permits the indirect assignment of the theta-role.



In cases of passive sentences and relatives clauses (examples (11) and (12)), both movement and traces are involved. As we have seen, traces are crucial for a proper assignment of thematic roles and semantic interpretation. In addition, all these structures share the fact that a trace occupies the object position in their S-structure representation, unlike those that involve transformational movement but that Broca's aphasics interpret above chance. This is the case of utterances such as (13a), which contrasts with sentence (13b) because its trace occupies the subject position.

- (13) a. $[_{DP} \text{The boy}]_i$ who $[t'_i [_{VP} t_i \text{ hit the girl}]]$ is tall.
 b. $[_{DP} \text{The boy}]_i$ who $[_{VP} t'_i \text{ hit } t_i]$ is tall.

Considering all these data, Grodzinsky (1986; 1990) postulated a hypothesis in order to account for agrammatic comprehension: the Trace-Deletion hypothesis.

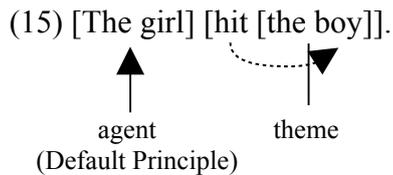
1.2.2. The Trace-Deletion hypothesis

The Trace-Deletion hypothesis (hereafter, TDH) was developed in the late 80s by Grodzinsky (1986; 1990) and revised since (Grodzinsky, 1995a,b; 2000b). It consists of a description of agrammatic representation of structures that Broca's aphasics cannot comprehend. The impairment was thought to be restrictive and syntactic in nature, that is, patients were thought to retain most of their syntactic knowledge and processes intact and that the deficit would only affect certain syntactic processes. In addition, the production and the comprehension deficit were not thought to be parallel.

After reviewing all the experimental data, Grodzinsky first (1984b; 1986) postulated that all traces were deleted from aphasics' representations of S-structure level. Hence, theta-role assignment failed in cases where traces were involved. Obviously, this account did not suffice to explain aphasics' linguistic behaviour, since they were able to interpret other structures which involved transformational movement and traces. According to the VP-internal subject hypothesis (Kitiwaga, 1986; Kuroda, 1986; Koopman & Sportiche, 1988), even subjects of active sentences are derived from D-structure by transformational movement leaving a trace in the original subject position. According to the TDH, structures of this kind would trigger at-chance performance by Broca's aphasics in comprehension tasks. Yet, patients are able to understand several structures which involve traces. Utterances in (14) exemplify syntactic constructions in which Broca's aphasic patients do not show an impaired comprehension:

- (14) a. [The girl]_i [t_i hit [the boy]].
- b. [The girl]_i who t'_i [t_i hit [the boy]] is tall.
- c. [The girl]_i [t_i was interested] in the boy.

Despite the transformational movement and the deletion of traces, Broca's aphasics can comprehend active sentences like (14a) and subject relative clauses like (14b); and even some passive sentences like (14c). All these syntactic constructions have in common the fact that their traces occupy the subject position. In order to explain correct theta-assignment in these cases in which traces are deleted, some cognitive strategies were postulated. Given that traces are deleted in disrupted language, some DPs would not receive a theta-role. This fact would violate the Theta-criterion and, hence, a Default Principle is used as a nonlinguistic strategy to compensate. It assigns a theta-role to constituents that are in nonthematic positions in a linear way, that is, it assigns the role of agent to the first constituent of an utterance. This strategy is useful to interpret sentences such as those in (14), since it compensates the disrupted process of indirectly assigning theta-roles resulting from the deletion of traces. Hence, for example (14a), the impaired representation and assignment of theta-roles as follows:



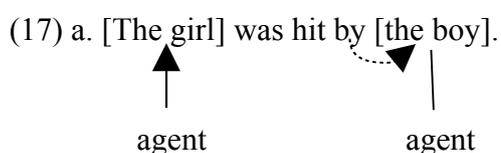
The theme role is assigned syntactically by the verb, while the agent role is assigned to the nonthematic position of the subject through the Default Principle. So, whenever the displaced constituent occupies the subject position and is an agent, the Default Principle will suffice and compensate the comprehension deficit.

Some passive sentences, such as (14c), lexical passives, behave in a similar way because they differ from the so-called “verbal passives”. Lexical passives are base-generated and are not the result of a transformational movement (besides that of the subject which moves from the VP-internal subject position to the external subject position):

Hence, the Trace-Deletion hypothesis consists of these two steps: (1) deletion of traces from S-structure and (2) application of a linear nonlinguistic strategy: the Default Principle. Yet, in spite of the compensation strategy, Broca’s aphasic patients fail in comprehending some utterances which involve traces in the object position, such as those represented in (16):

- (16) a. [The girl]_i was [t_i hit t_i] by the boy.
 b. [The girl]_i who [the boy [t_i hit t_i]] was tall.

Broca’s aphasic patients perform at chance in interpreting reversible passives like (16a) or object relative clauses like (16b). Assuming that all traces are deleted with the consequence that theta-roles cannot be transmitted through the common index, the Default Principle must be invoked. This would be the agrammatic representation for sentences (16a) and (16b):



b. [The girl] who [[the boy] hit] was tall.



There is an agent role assigned syntactically in both sentences by the verb, and another agent role assigned by the Default Principle to the first constituent in a clause. According to the Theta-criterion, a thematic role cannot be assigned to more than one argument within the same clause; hence, in these assignments there is a conflict among thematic roles and aphasics have to guess, since other cognitive strategies such as heuristics would not be useful in reversible sentences. The TDH predicts chance performance in syntactic structures of this kind.

There is still one kind of sentence in which aphasics' performance is below chance: passives with psychological verbs (e.g: *hate, love, admire...*). The theta-grid of a psychological verb differs because an experiencer role is assigned to its subject—instead of agent role—and a theme role to its object. In passive sentences such as (18), after all traces have been deleted, the experiencer role is assigned syntactically to the object position by the preposition, but the determiner phrase in the subject position remains without a thematic role. Then, the Default Principle operates and assigns a default role, an agent, to the first determiner phrase of the utterance. Two different thematic roles can coexist without causing any competition among equals, that is the reason why Broca's aphasic patients do not guess, as they do in agentive passives, and their performance is less successful.

(18) [The girl] was admired by [the boy].



The TDH has been tested in different languages (among others, Hagiwara & Caplan (1990) and Hagiwara (1993) for Japanese; and Beretta & al. (1996); Beretta & al. (2001) and Baauw & al. (2004) for Spanish) and it has been reported that default strategies depend on the properties of aphasics' language. In fact, basic word order determines the theta-role that is going to be assigned to the first DP in a nonthematic position. In English, for example, the basic word order is SVO; hence, agent is the

thematic role first assigned by the Default Principle. This is why it is interesting to test comprehension of Broca's aphasic patients who speak languages with different word orders. Some Romance languages have more flexible word order properties than English, as is the case with Spanish or Catalan, where constructions with a noncanonical word order are commonly used, even in active sentences. It is easier, then, to test whether linear default strategies, like the Default Principle, work in different languages.

1.3. Comprehension in Catalan agrammatics

Syntactic properties of Catalan are interesting to test the TDH and the linearity of the Default Principle, even though only one study has been carried out on the word order comprehension of Catalan-speaking aphasics (Gavarró, 2005). Catalan is a null-subject language (Rizzi, 1982) and, besides the basic word order (SVO), it includes sentences with a noncanonical word order, like object-contrastive focus constructions. Contrastive focus is used in order to stress certain information of an utterance, and especially to contrast new information with the presupposed belief of the listener (Rizzi, 1997). Sentence (19), from Rizzi (1997), exemplifies an object-contrastive focus construction. The contrastive focus, *il tuo libro*, contrasts with the presupposed belief indicated within the parentheses:

(19) a. [IL TUO LIBRO] ha letto lei (, non il suo).

Det-ms your book read-3s she

'Your book she read (, not his)'.

In this structure, in Italian and Catalan (see examples (20) and (21)), the object appears in an initial and preverbal position (the typical subject position), while the subject comes after the verb (OVS). This construction is ambiguous for unimpaired speakers, except for those cases in which verb-subject agreement disambiguates the meaning of the sentence, as in example (20):

(20) LA MARE, abbracen les nenes.

Det-fs mother hug-3p det-fp girl-p

'It is the mother who the girls hug'.

Here, the verb and subject agreement indicates that the subject and agent must be the constituent in the rightmost position, since the object has a different number. However, sentence (21) is ambiguous because both the object (*la mare*) and the subject (*la nena*) could agree with the verb. Yet, contrastive focus is marked with a characteristic intonation (represented orthographically with capital letters).

(21) LA MARE, abraça la nena.

Det-fs mother hug-3s det-fs girl

‘It is the mother who the girl hugs’.

In contrastive focus statements, the inversion of the constituents is derived by the movement of a constituent to a left-peripheral position and, according to the TDH, agrammatic representations delete all traces and, thus, the transmission of thematic roles is disturbed. Then, by hypothesis, a Default Principle is applied in order to assign a theta-role to those constituents that have not received it through the trace. As we have already mentioned before, the Default Principle is a nonlinguistic strategy and, hence, it assigns thematic roles in a linear way, depending on the basic word order of each specific language. Since the basic word order in Catalan is SVO, we would expect Catalan aphasics to interpret contrastive focus sentences with inverse order, as in (22b), as active sentences with canonical order (SVO), like example (22a).

(22) a. [El cavall] [persegueix [la girafa]]

Det-ms horse chase-3s det-fs giraffe

‘The horse chases the giraffe’

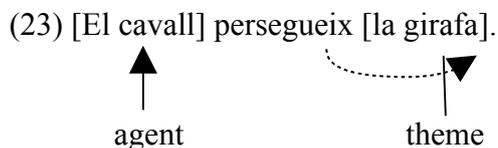
b. [LA GIRAFA], persegueix [el cavall]

det-fs giraffe chase-3s det-ms horse

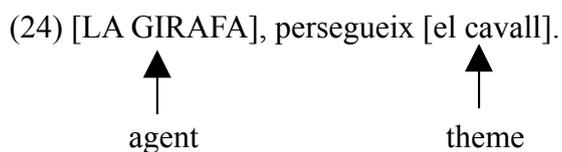
‘THE GIRAFFE, the horse chases’

Gavarró (2005) has actually reported this phenomenon and carried out a pilot study with two Catalan-Broca’s aphasics, in order to find out whether the TDH’s predictions accounted for Catalan aphasics’ abilities in comprehending ambiguous sentences. Their comprehension was tested in tasks which involved actives and subject focus sentences, that is, sentences that presented the basic word order, as in example (22a). Broca’s aphasics were supposed to be able correctly to interpret them, given that the linear

default strategy would assign the agent role to the first constituent—in the subject position—without a thematic role, while the verb would assign directly the theme role to its object:



And, in fact, both patients tested performed above chance. Gavarró (2005) also introduced contrastive focus sentences with the object in first position, like example (22b). According to the TDH, aphasics' performance would be below chance, since the linear strategy would assign agenthood to object and a theme role to subject:



However, Gavarró (2005) reports at-chance performance results. Hence, the TDH and Default Principle predictions are inaccurate in these cases.

Other relevant structures for the TDH reexamination are those constructions involving dislocations to the left periphery. The interesting property is that they have been argued not to be derived by movement (Cinque, 1990). Hence, thematic roles are assigned directly to constituents and, by hypothesis; Broca's aphasics should not have any problems in theta-role assignment, even though they present noncanonical word order. This is the case of clitic left dislocations (hereafter, CLLD), such as topicalization. Topicalization is used to isolate the old information in an utterance, in order to emphasize that new information about the topicalized item is going to be introduced (Rizzi, 1997). Thus, the topicalized constituent is already familiar to the listener, while the rest of the utterance is completely new. The topic appears in the leftmost position in the sentence and, when it is an object, a resumptive pronoun (clitic) is required. In (25), an Italian topic construction exemplifies this (Rizzi, 1997):

(25) [El libro], l'ho letto.

det-ms book CL-3s read-3s past

'The book, I read it'

The TDH's predictions on comprehension of structures which do not involve movement contrast sharply with predictions on comprehension of structures which do involve movement. By hypothesis, Broca's aphasics have no impairment in syntactic assignment of theta-roles, so, they should be able to comprehend sentences such as (25), even though it presents a noncanonical word order. Given that the TDH's predictions are inaccurate for object-contrastive focus structures (Gavarró, 2005), it would be interesting to see how Broca's aphasics behave in apparently similar sentences but with completely different structures. A further study would help to reexamine the TDH and to reach a more precise description of agrammatic comprehension.

1.4. Goals of the present study

Hence, as we have already pointed out, if the Default Principle does not suffice as a cognitive strategy to explain Broca's aphasic patients' interpretations of constructions represented in 1.3., further research will be needed in order to reexamine the TDH and strategies used to compensate the deficit. Besides testing contrastive focus statements, there are other Catalan constructions that involve movement and that may prove interesting to test. In fact, we could also consider structures involving the left periphery such as interrogative sentences and clitic left dislocations. The latter (described in 1.3) are especially interesting, given that there is no extant study on aphasics' comprehension of these structures and, in addition, constructions of this kind have an interesting property, because they have been argued to be derived without movement (Cinque, 1990). As we have said before, this has important consequences, since thematic roles are directly assigned to syntactic positions instead of being assigned through a common index that the displaced constituent and the trace share. Hence, Broca's aphasics should interpret correctly these structures, even in cases where the object appears in the initial position and the word order is not canonical. So, their performance should be above chance, contrasting with the results of tasks involving other constructions like reversible passives, object relative clauses or object-contrastive focus sentences. Sentences (26)

exemplify an active sentence with the basic word order (26a), an object-contrastive focus in the leftmost position (26b) and a CLLD objects in initial position (26c).

- (26) a. [La mare] veu [el pare]
det-fs mother see-3s det-ms father
'The mother sees the father'
- b. [EL PARE], veu [la mare]
det-ms father see-3s det-fs mother
'It is the father that the mother sees'
- c. [El pare], el veu [la mare]
det-ms father CL-ms see-3s det-fs mother
The father, the mother sees him.

According to the TDH, and as we have mentioned before, Broca's aphasics are expected to perform above chance in tasks involving active sentences, like (26a). It has been predicted for utterances like (26b), contrastive focus statements, that Broca's aphasics would perform below chance. However, Gavarró's pilot study (2005) has shown that this prediction may not be accurate and needs to be reexamined. Finally, above chance performance is predicted for constructions such as (26c), topics, since no transformational movement is involved. Hence, we think that it would be interesting to test aphasics' comprehension of Catalan contrastive focus and topic, given that both structures put the TDH to test and have been almost unexplored.

Yet, these constructions also have special properties in other linguistic levels. In fact, both structures present a characteristic intonational contour that allows listeners to distinguish one from another. We have orthographically marked contrastive focus intonation with capital letters (see example (26b)) and marked topic with a comma that is intended to reproduce the optional pause of topic intonation (see example (26c)). If the meaning is indicated by phonological properties, this could aid aphasics to interpret object-contrastive focus and topic sentences.

Burchert et al. (2005) carried out an experiment in order to find out whether different intonational contours helped subjects to distinguish contrastive focus from neutral

statements; however, it seemed that intonation did not benefit aphasics. This fact could either be due to impairment at a phonological level or result from an interpretation that mostly relies on syntactic properties of utterances. This is why we propose first to test aphasics' abilities in distinguishing intonational contours, in order to find out whether agrammatics can use that ability at all in sentence comprehension. In addition, a pilot study on the phonological abilities in agrammatic comprehension would confirm whether the deficit is specifically syntactic, as is postulated within the TDH framework. If Broca's aphasics were not able to distinguish intonational contours, a phonological deficit should be postulated and it would make no sense to test for syntactic knowledge or processes. Hence, Grodzinsky's account of agrammatic comprehension would have to be challenged, since he describes agrammatic comprehension as a disturbance of certain syntactic processes. Yet, if Broca's aphasics can distinguish intonational contours, and given that intonational patterns are crucial for a correct interpretation of these utterances in unimpaired language, any deficit in comprehension has to be attributed to syntax (other sources excluded).

Therefore, the aim of the present study is to find out whether Catalan-speaking aphasics are sensitive to intonational patterns and, especially, to those that characterize contrastive focus statements and topics. The main goal is to characterize agrammatic comprehension by assuring that the impairment affects only certain syntactic processes and later to continue the study with further research about the nature of the syntactic disturbance and the accuracy of the TDH predictions. The results of the present study could prove of some importance for the interpretation of experiments concerning aphasics' comprehensive skills in sentences which present noncanonical order, such as contrastive focus or topic in Catalan. In addition, the present study could also contribute to studies on aphasias focused on the phonological level, given that the field is almost unexplored (especially in the Romance languages).

2. Intonational contours in healthy and agrammatic speakers

2.1. Framework

2.1.1. The Autosegmental-Metrical Model

Prosody is the part of phonology which includes rhythm, stress and intonation. Intonation can help not only to express a speaker's emotion but also has linguistic meaning. In the generativist account of intonation by Chomsky and Halle (1968), the phonological realization of an utterance depends on its syntactic properties, in the sense that the intonational contour is generated from the deep structure. After Chomsky & Halle's (1968) work, some researchers developed several systems of prosodic representation. Among these systems is, as Ladd (1996) called it, the Autosegmental-Metrical Model (AM Model hereafter), which began with Pierrehumbert's thesis (1980), where she proposes an analysis of English intonation. The antecedents of the AM Model are, on the one hand, some proposals for tonal languages' analysis (Goldsmith, 1976) and, on the other hand, metrical studies of intonation (Lieberman, 1975). From the former studies, Pierrehumbert took the autosegmental analysis, which consists in representing the intonation as a separated level from other phonological features. In order to describe the melody, sequences of tones that were related to the segmental level were used; in this way, each syllable can be associated independently with a tone (example (27)). Tones are contrastive elements in tonal languages and only a few of them are postulated (mid, high and low tones) to be primitive. Pierrehumbert (1980) took just two of them: a high (H) and a low tone (L).



Pierrehumbert (1980) adapted the autosegmental model, which was mainly conceived to describe the intonation of tonal languages, to her analysis of English intonation (an intonational language). Her work was influenced by the theory of metrical phonology (Lieberman, 1975), which claimed that tones were associated with syllables depending on the prominent points of an utterance. Thus, the relationship between the segmental

level and the melody is metrical, because it is reduced to those syllables pronounced with more prominence (lexical accented syllables). The last syllable uttered with more prominence, which is called the nuclear accent, carries the most important information about the intonational contour. In intonational languages, tones are supposed to carry pragmatic information (such as the intention of the speaker), but they do not change the lexical meaning of the words. In fact, words usually have a lexical fixed accent (although there are some unstressed words, like some prepositions) to which a prosodic tone can be attached.

The main characteristic of the AM model is the division of different levels (Pierrehumbert, 1980; Beckman & Pierrehumbert, 1986), two of them crucial for intonation characterisation (Figure 2): the intonational phrase (ι) and the phonological or intermediate phrase (φ or ip). The former is a high level in the phonological hierarchy (only below the utterance level) and contains at least one of the latter phrases.

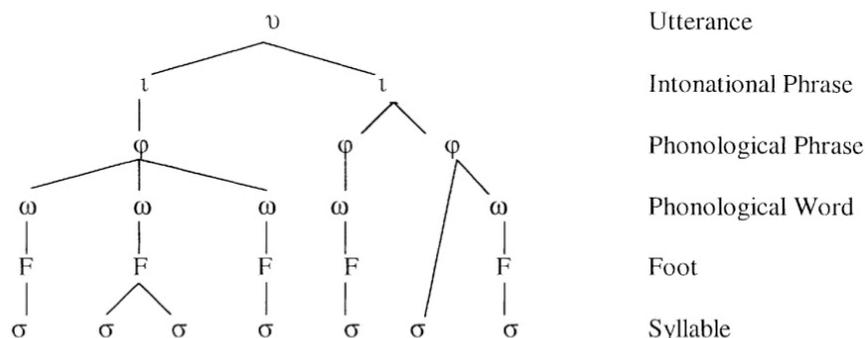


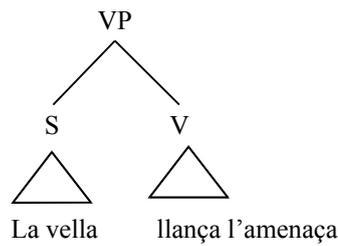
FIGURE 2. Representation of the hierarchical organization of phonological constituents. Source: GUSSENHOVEN (2002)

The edges of an intermediate phrase show a lower degree of separation between contiguous prosodic units, but still mark a prosodic unit. These units are related to the syntactic properties of the utterance (Chomsky & Halle, 1968) and often help listeners to interpret the meaning of ambiguous sentences.

(28) a. {[La vella] [llança l'amenaça]}

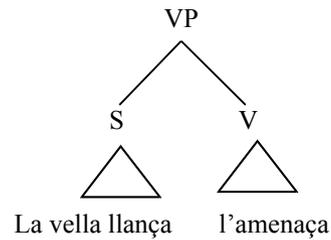
Det-fs old-lady throw-3s det-fs threat

'The old lady threatens her/him'



Det-fs old-spear CL3s threaten-3s

'The old spear threatens him/her'



b. {[La vella llança] [l'amença]}

Both examples (Prieto, 2002c) contain two intermediate phrases (marked with square brackets), but have different syntactic properties which are reflected in the intonational characteristics of the utterances. In (28a), the first prosodic unit only includes “la vella”, while in (28b), the first intermediate boundary tone is placed after the word “llança”. This contributes to disambiguate the meaning of these utterances, since the prosodic properties tell us whether “llança” must be interpreted as a verb (as in (28a)) or as a noun (as in (28b)).

According to Pierrehumbert's thesis (1980), there are two kinds of tones: pitch accents and boundary tones. Pitch accents can be either low (L) or high (H) and are related to lexical stressed syllables which show more prominence (in order to show this relationship with the accented syllable, they are always orthographically marked with an asterisk (*)). When they are not realized as a H tone or a L tone, but rather as a rising or falling movement during the accented syllable, a bitonal signal is used; one of its two tones marked with an asterisk and produced on the accented syllable, and the other one displaced either on the posttonic or pretonic syllable. In figure 3, there is a representation of a possible tone which is realized as a high tone on the pretonic syllable and a fall within the accented syllable.



FIGURE 3 . Representation of H+L*. Source: Prieto (in press)

Pierrehumbert's thesis (1980) postulated tones of another kind, boundary tones. These are realized at the edge of the intonational phrase (marked with a % sign). Later, Beckman & Pierrehumbert (1986) added the notion of intermediate boundary tones (marked with a dash) that are produced at

the end of the intermediate phrase, between the last pitch accent and the final boundary tone.

An initial boundary tone was postulated by Pierrehumbert & Beckman (1988) for the prosodic analyses of Japanese intonation, where the tone is associated with the beginning of the intonational phrase (marked with a % sign as well). Later on, it was also included in other languages' transcription systems. The intonational contour of Catalan interrogative sentences headed by the conjunction *que* are often transcribed with an initial boundary tone (Prieto, 2002b; Prieto & Rigau, 2007), as is exemplified in (29), from Prieto, 2002b):

(29) Que veureu la Maria?
 That see-2p Det-fs Maria
 'Are you going to see Maria?'

As we have mentioned above, the most important part of intonational patterns is the nuclear contour, which goes from the last tonic syllable to the end of the utterance (including the last pitch accent and final boundary tones). A lot of prosodic and linguistic information is carried by the nuclear contour. All utterances must have, at least, a nuclear pitch accent, an intermediate boundary tone and a final boundary tone (Figure 4).

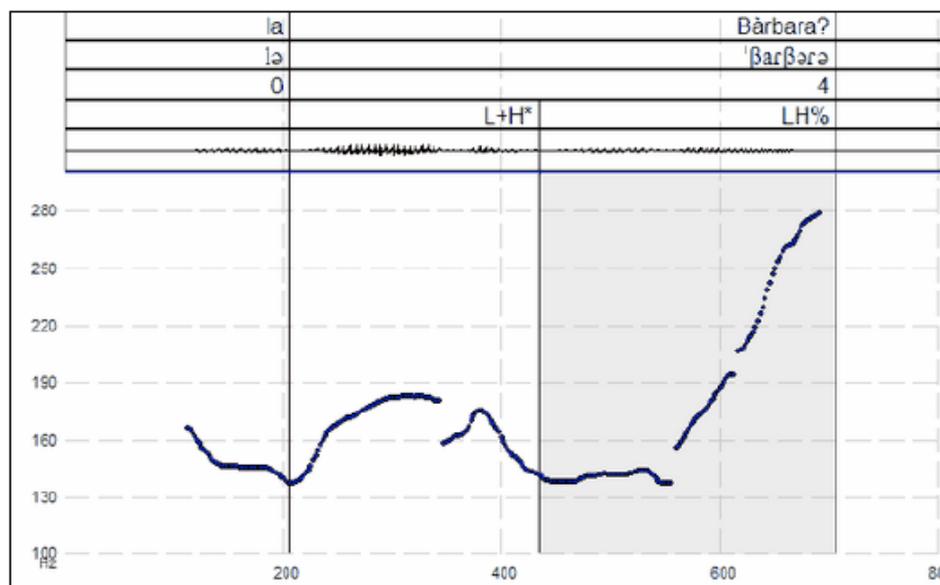
$$\left(\%H \right) \left(\left(\left(\left(\begin{array}{c} H^* \\ L^* \\ H^* + L \\ L^* + H \\ L + H^* \\ H + L^* \end{array} \right) \right) \left\{ \begin{array}{c} H^- \\ L^- \end{array} \right\} \right) \left\{ \begin{array}{c} H\% \\ L\% \end{array} \right\} \right)$$

FIGURE 4. Representation of the prosodical structure of an utterance. Initial boundary tones are optional, while utterances must have at least one pitch accent and, at the end, a nonfinal and a final boundary tone. Source: GUSSENHOVEN (2002).

2.1.2. Catalan intonation

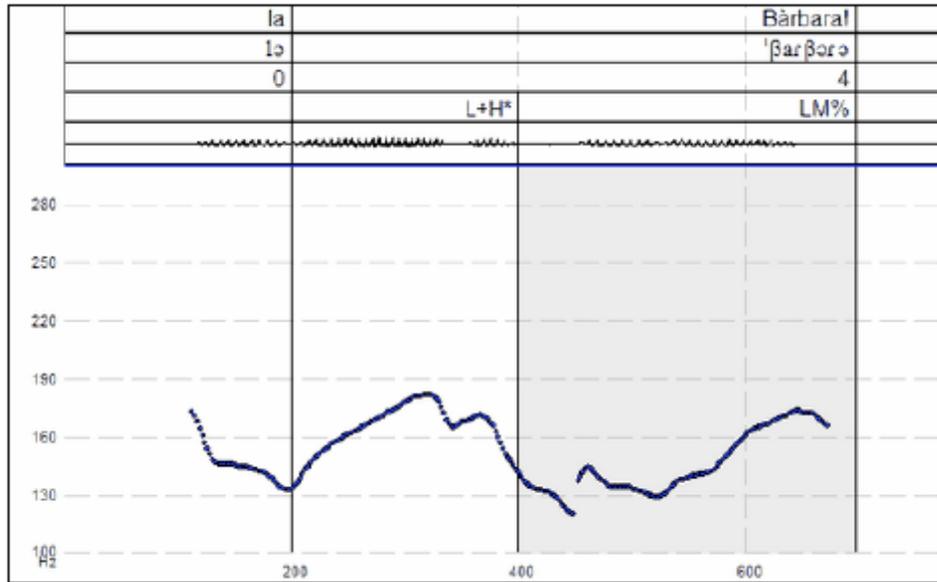
Depending on the intonation function, languages are classified in three groups: tonal languages, languages with melodic accent and intonational languages. In tonal languages, like Chinese, each syllable is associated with a specific tone, and these are contrastive and have lexical meaning. On

the other hand, languages with melodic accent (like Japanese) only associate tones with accented syllables, since lexical accent appears systematically and its prominence is not affected by the general contour. Catalan belongs to the third group, in which tones are not necessarily associated with all the syllables of an utterance. In addition, tones are not lexically contrastive, but are used to report the speaker's attitude or intentions and organize the message. Contrary to languages with melodic accent, the F0 values of intonational languages are regulated by the general contour. The same syllable can be produced either with a high or a low tone, depending on the general pattern and without affecting the meaning of the utterance. As an example, in figures 5 and 6, the same utterance, “La Bàrbara”, is produced in two different prosodic contexts. In Figure 5, we have an incredulity question and, as can be observed, the F0 contour is realised with a general rising contour. In fact, the nuclear configurations consists of a rise on the accented syllable (L+H*) and a final boundary tone realized as a rise as well (LH%). On the other hand (Figure 6), the context of the same utterance in Figure 5 is an obviousness statement; so, the pitch accent is realised as a rise (L+H*) and the low boundary tone (LM%) contrasts sharply with the rising boundary tone in Figure 5.



- Demà ve la Bàrbara.
- *La Bàrbara?* No és fora?
- Barbara is coming tomorrow.
- *Barbara?* Isn't she abroad?

FIGURE 5. Prosodic labelling and context of the utterance “La Bàrbara?”, an incredulity question. Source: Prieto, in press



- Qui vindrà demà?
- *La Bàrbara* (òbviament)!
- Who is coming tomorrow?
- *Barbara* (of course)!

FIGURE 6. Prosodic labelling of the utterance “La Bàrbara!”, an obviousness statement. Source: Prieto, in press.

Hence, intonation in Catalan does not have the capacity of attributing lexical meaning, but it does have other functions. As we have already mentioned, intonation can be used in order to organize a discourse (demarcative function), to report speaker's attitude or intentions (expressive function) or to rank some information (focalize).

The first study about Catalan intonation was published in 1971. In it, Virgili Blanquet compared Catalan and Spanish declaratives. Later on, some studies on Central Catalan dialect intonation were released (Recasens, 1977; Bonet, 1984; Prieto, 1995; 2002b; Estebas Vilaplana, 2000, 2003) and several researches tried to account for a description of other dialectal varieties (Mascaró Pons, 1986, 1987; Prieto, 2001; Prieto & Padrilla, 2004; Martínez Celdrán et al., 2005a, 2005b; Vanrell, 2006; Prieto & Rigau, 2007).

2.1.3. Tones and Break Indices, a transcription system

Several transcription systems have been developed within the AM framework, among them, the ToBI system. It was first developed in order to reach a common standard

system for transcribing the intonational patterns of English utterances and share the current data (Silverman et al., 1992; Beckman & Hirschberg, 1993; Pitrelli et al., 1994), and it was later adapted in other languages and dialects (it is possible to consult all ToBI systems on the web page of Ohio University, <http://www.ling.ohio-state.edu/~tobi/>). Prieto, Aguilar, Mascaró, Torres and Vanrell (2009) made the Catalan version (Cat_ToBI) on the basis of a large corpus of spoken Catalan, including different dialects¹ and previous studies on Catalan intonation (Bonet, 1984; Prieto, 1995, 2007; Font, 2007 and others).

In the Cat_ToBI system, five tiers of analysis are distinguished: a break index tier, a tone tier, an orthographic tier (orthographic transcription), a phonetic tier (phonetic transcription), and a miscellaneous tier (comments and other markings).

On the break index tier, the degree of juncture perceived between units is annotated. The main criterion used is the auditive perception of the transcriber, even though break indices values and general indications are reported in Prieto, Aguilar, Mascaró, Torres and Vanrell (2009):

- 0 Mark cohesion between orthographic words (see Figure 7).
- 1 Mark boundaries between prosodic words (see Figure 7).
- 2 Mark boundaries between phonological phrases (see Figure 7).
- 3 Mark boundaries between intermediate phrases (see Figure 7).
- 4 Mark phonological phrases' boundaries (see Figure 7).

Some of these break indices are exemplified in Figure 7, in which the utterance (30), in Majorcan Catalan, has been prosodically analysed and labelled:

- (30) On vas, com hi vas i quan tornaràs?
where go-2s, how there go-2s and when be back-2s,f
'Where are you going? How are you getting there? And when will you be back?'

¹ Speech materials can be found on the web page of *Interactive Atlas of Catalan Intonation* (<http://prosodia.upf.edu/atlesentonacio/index-english.html>).

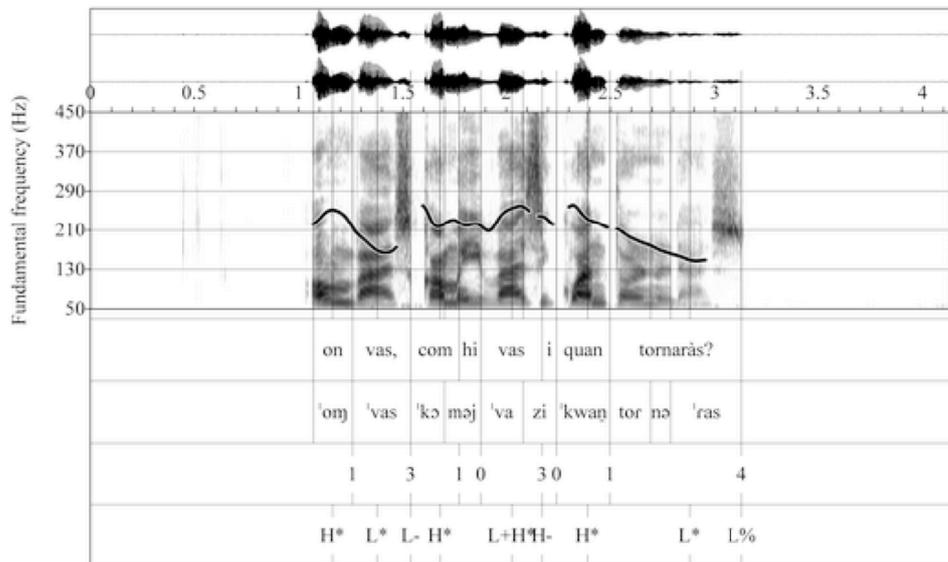


FIGURE 7. Prosodic labelling of the utterance (30). Source: http://prosodia.upf.edu/cat_tobi/en/index.php

The tone tier will be used for tonal representation. As we have said, there are two kinds of tonal units: pitch accents (which are associated with accented syllables and are marked with an asterisk) and boundary tones (which are related to boundaries of phonological and intermediate phrases). In the Cat_ToBI system, only two tonal levels are recognised: high (H) in the local pitch range and low (L) in the local pitch range (Pierrehumbert, 1980²). Pitch accents can be either monotonal (H*, L*) or bitonal (L+H*, L+>H*, L*+H, H+L*). The > sign (from Beckman et al., 2005) is used to express that the rise of the F0 is extended to the posttonic position.

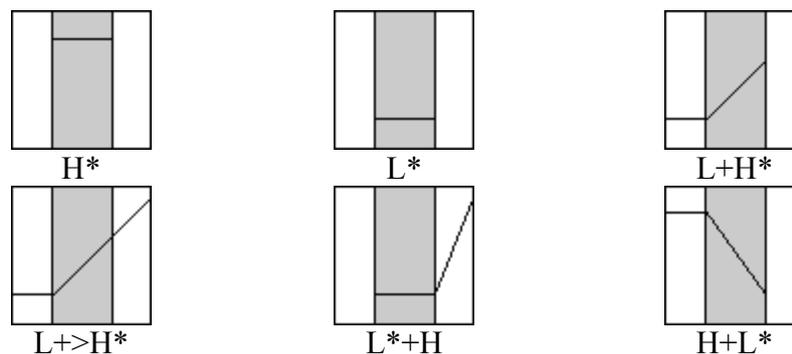


FIGURE 8. Main pitch accents in Catalan. Source: Prieto, Aguilar, Mascaró, Torres and Vanrell (2009)
 Prieto, Aguilar, Mascaró, Torres and Vanrell (2009) have proposed omitting boundary

² Pierrehumbert (1980) claims that pitch range may vary among speakers but that it doesn't need to be phonologically represented, since it is use expressively and it doesn't have linguistic meaning.

tones, as other researchers (Sosa, 1999; Beckman et al., 2002) had suggested earlier in their proposals for Spanish intonation transcription. These authors consider that tones of this type are not necessary to reach a complete description of Catalan contours, given that the nucleus is located at the edge of prosodic phrases, and that complex boundary tones can appear on the edge of either a phonological or an intermediate phrase. Thus, there are only boundary tones, either monotonal, bitonal or tritonal. Besides the high and low tonal levels, there is an additional tonal level for boundary tones: a medium final boundary tone (M%), in order to distinguish a medium rise from a complete rise (Prieto, Torres & Vanrell, 2009). And, as we noted earlier, a high initial boundary tone (%H, see Figure 10) can be transcribed in some contexts. The other final boundary tones are all transcribed and represented in Figure 9:

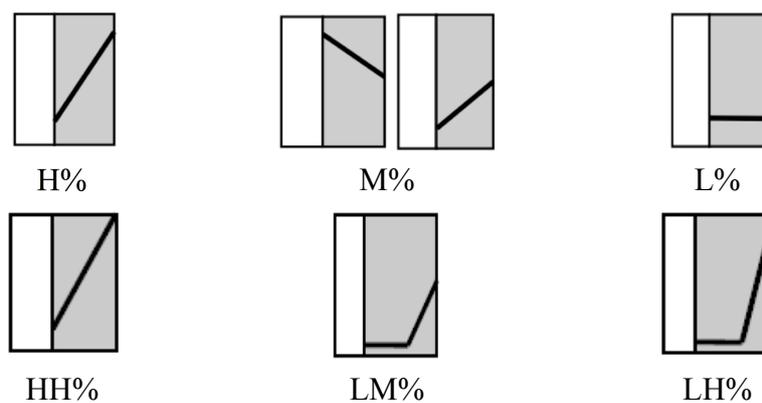


FIGURE 9. Final bitonal boundary tones in Catalan. Source: Prieto (in press)

Figure 10 exemplifies one of the common pitch accents and boundary tones in Catalan. The utterance (31) is a falling yes-no question, which is very typical of questions introduced by the conjunction *que*. The last accented syllable is performed as a falling tone and the contour is concluded by a final low boundary tone.

- (31) Que l'hi duries?
 that CL3s pron take-2s
 'Would you take it to him/her?'

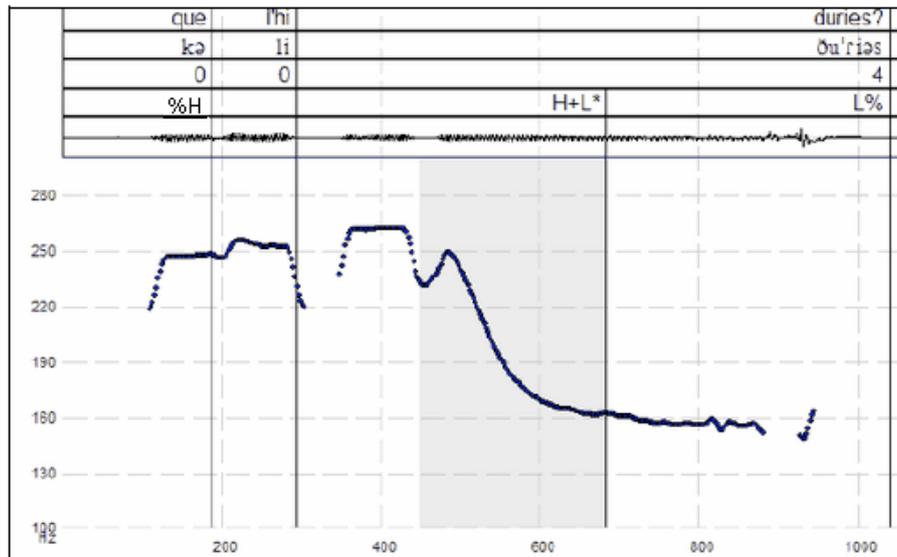


FIGURE 10. Prosodic labelling of the utterance in (27), Source: Prieto, 2002b

The basic nuclear configurations in Catalan are reported by Prieto (in press) and Prieto et al. (2009); remember that the nucleus of prosodic patterns appears on the edge of utterances, and consists of the rightmost pitch accents and final boundary tones. Hence, nuclear accents are the main characteristic of a prosodic pattern, since they are crucial for interpretation. In Catalan, 16 types of different nuclear configurations have been found (see http://prosodia.upf.edu/cat_tobi/en/index.php), among them, the nuclear contour (L* L%) which is typically associated with neutral declaratives (Figure 11), but which also characterizes prosodic units that are not focalized or topicalized, when a focus (Figure 13) or a topic occurs (Figure 14). This type of contour differs from neutral yes-no question realization, which, in Catalan, can be uttered either with a rising (L* HH%, see Figure 12) or falling contour (H+L* L%, when the question is introduced by the conjunction *que*). Narrow focus statement (Figure 13) has also a characteristic intonational pattern (L+H* L%), since it consists of an independent prosodic unit.

In Table 1, neutral declaratives, narrow focus statements and yes-no questions are represented in a schematic way; in addition, we have added some other contours (wh-questions and obviousness statement) in order to show the contrasts that distinguish one contour from another.

Schematic	Cat_ToBI label	Context
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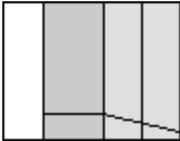
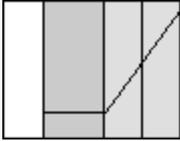
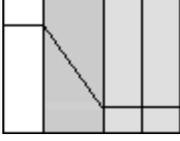
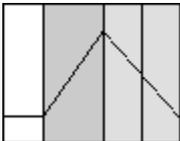
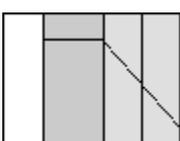
Contour		
	L* L%	Neutral Declarative
	L* HH%	Neutral yes-no question (rising)
	H+L* L%	Neutral yes-no question (falling)
	L+H* L%	Narrow focus statement
	H* L%	Wh-question
	L* HL%	Obviousness statement

TABLE 1. Schematic representation, Cat_ToBI label and context of some Catalan nuclear configurations.
Source: Prieto, in press

2.2. Prosodic analysis of relevant contours

Following the AM framework and Cat_ToBI conventions that have been set out above, we analysed and transcribed the four intonational contours that were used in the experiment. The intonational patterns were neutral declaratives, neutral yes-no questions (rising), narrow focus statements and a topic.

The typical intonation for **neutral declaratives**—in Central Catalan—is a general falling F0. The prenuclear contour is characterized by a rising high pitch accent on the

first stressed syllable, which consists of a low pitch accent that is extended through the accented syllable (marked with a > sign) and displaces the high tone to the posttonic syllable. The prenuclear configuration is followed by a low pitch accent on the nuclear stressed syllable. The pitch falls until the end of the intonational phrase and ends with a low final boundary tone. Figure 11 exemplifies the intonational contour described with one of the utterances that we used, *En Pere toca el piano* “Pere plays the piano”. On the first accented syllable, the low pitch accent is followed by a slight rising that reaches the posttonic syllable. Then, the intonational contour falls and the nuclear syllable is uttered with a low pitch accent and a low final boundary tone.

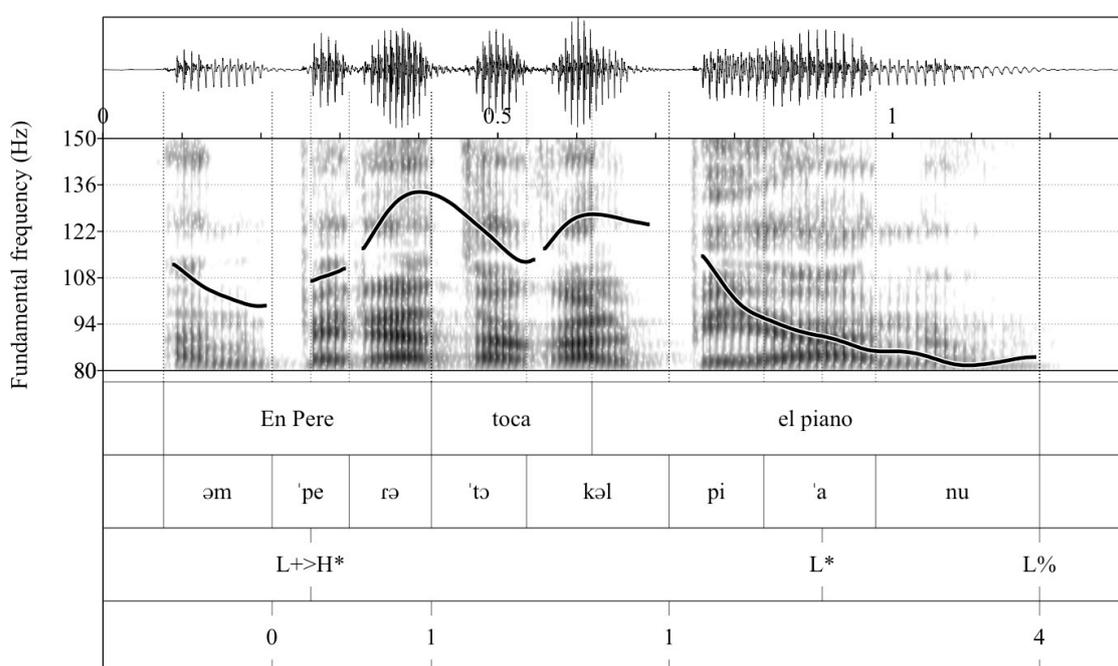


FIGURE 11. Waveform display, spectrogram, F0 contour, phonetic and orthographic transcription and prosodic labelling of the neutral declarative *En Pere toca el piano* ‘Pere plays the piano’

We have added some **yes-no questions** which present the opposite intonational contour of declaratives, that is, a rising F0. These types of contours start with a slight fall that stops on the first tonic syllable, where a low pitch accent is realized, and then the pitch rises during the posttonic syllables, to slightly fall again. The nuclear syllable is formed by a low pitch accent and the typical question’s final rising contour. In Figure 12 the contour described is observable in one of our experimental items, *En Pere toca el*

piano? “Peter plays the piano?”.

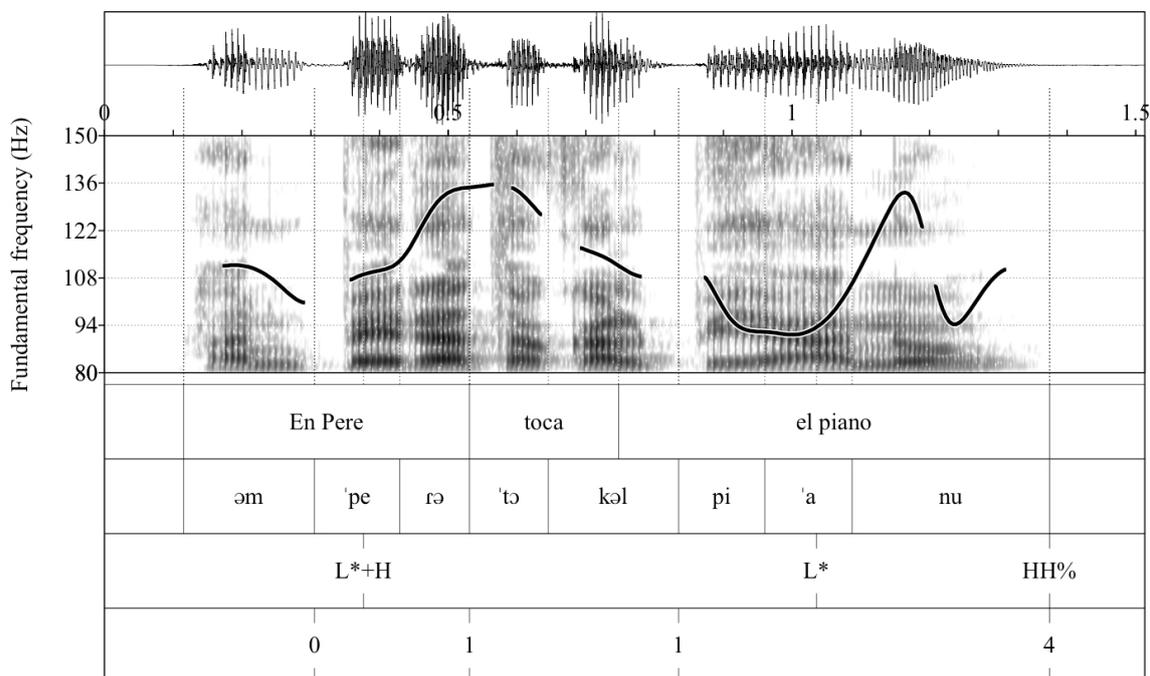


FIGURE 12. Waveform display, spectrogram, F0 contour, phonetic and orthographic transcription and prosodic labelling of the yes-no question *En Pere toca el piano* ‘Pere plays the piano’

The typical contour of a **narrow focus statement** is characterized by a prominent accentuation of the focused item. The tonic syllable of the focused constituent is accented by an emphatic high pitch tone, preceded by a rising low F0. After the high peak on the first stressed syllable, the F0 falls immediately to reach a low frequency. The item dislocated to the left constitutes the focus, since the displacement marks the constituent as an important item of the utterance. The second prosodic unit is deaccented. This fact induces its dependency on the first accented constituent. Figure 13 exemplifies this:

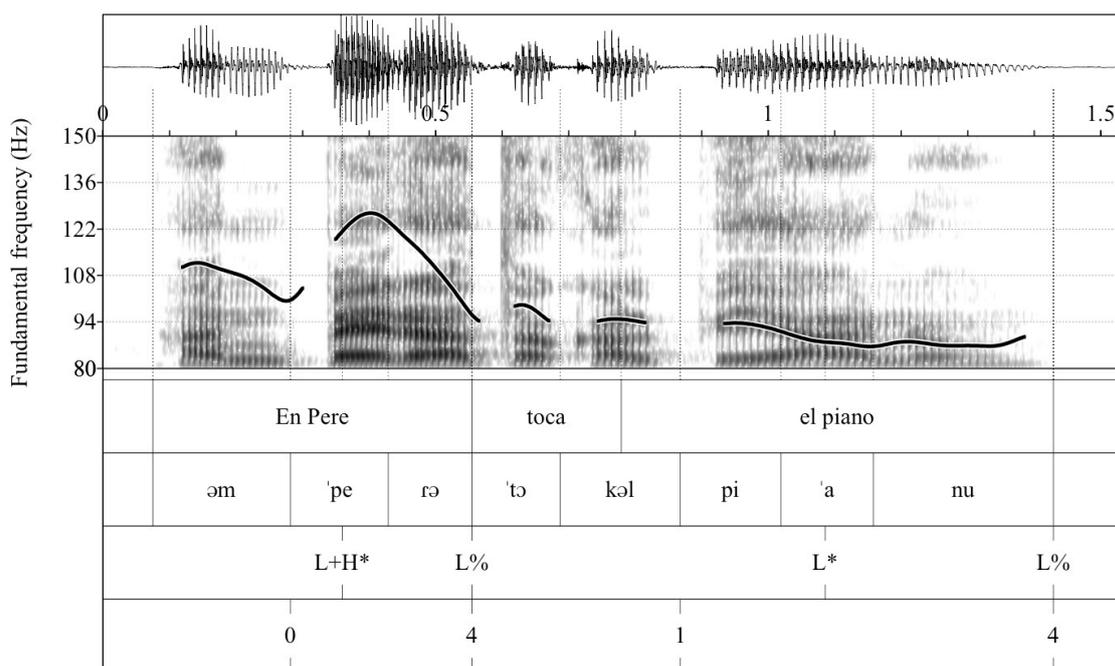


FIGURE 13. Waveform display, spectrogram, F0 contour, phonetic and orthographic transcription and prosodic labelling of the utterance (narrow focus statement) *En Pere toca el piano* 'Pere plays the piano'

A **topic** is prosodically marked as well. The topic constitutes an independent prosodic unit, clearly isolated from the rest of the utterance. An optional pause can be uttered after the topic in order to emphasize the autonomy of the topic. The first prosodic unit involves the topic itself (already known information) and it is formed by a rising F0, which is the typical frequency to leave the utterance unfinished and introduce a new prosodic unit (that depends in content on the first one). The second unit, which reports unknown information, is characterized by a falling contour (similar to the neutral declaratives' contour). In Figure 14, we can observe both prosodic units: the first one, with a rising pitch accent and a high final boundary tones the nuclear tone; and the second one, with a low pitch accent on the last stressed syllable and a low final boundary tone.

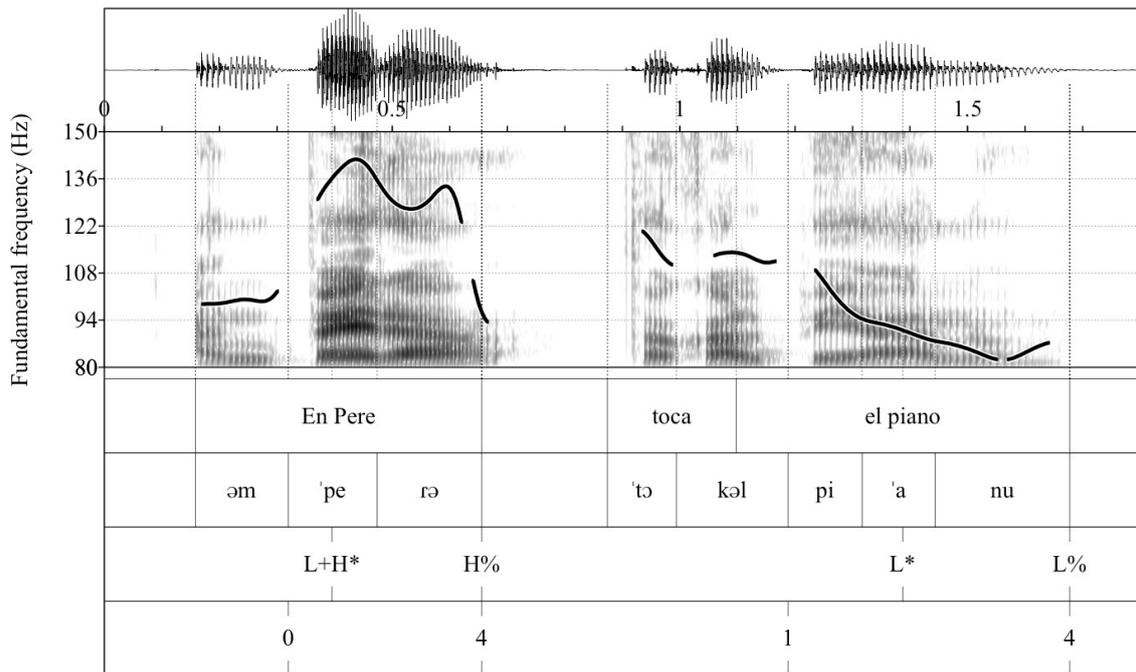


FIGURE 14. Waveform display, spectrogram, F0 contour, phonetic and orthographic transcription and prosodic labelling of the utterance (topic) *En Pere toca el piano* ‘Peter plays the piano’

2.5. Antecedents

Few experimental studies on prosody comprehension in Broca's aphasic patients have been carried out. Baum et al. (1982) conducted an experiment in order to test Broca's aphasics' comprehension of prosodic stress, and concluded that Broca's aphasics present a deficit, which is correlated with the severity of aphasia and affects their prosodic comprehension. Other studies have reported similar results (Solomon & Aronson, 1977), while others have claimed that prosody facilitated auditory comprehension (Blumstein & Goodglass, 1972; Blumstein & Cooper, 1974; Pashek & Brookshire, 1982; Kimelman and McNeil, 1982, 1989; Kimelman, 1991, 1999). However, most of these studies have focused on the effect of stress on the general auditory comprehension of spoken language, and not on the prosodic abilities of Broca's aphasics, like the recognition of intonational patterns. Later, Burchert et al. (2005) carried out an experiment in order to learn whether aphasics used prosodic features as a cue to their comprehension. Contrastive focus structures that presented a noncanonical order (OVS) in German were tested and compared to the results of two other studies (Burchert et al., 2003; Schneider, 2003), in which 22 object-contrastive focus structures with neutral intonation (declaratives) were tested. All the sentences were unambiguous, since the objects and subjects were case-marked (see example (32)).

(32) Den Vater sucht der Sohn.

Det-Acc father seek-3s det-Nom son

'It is the father who the son seeks'

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Four Broca's aphasics were asked to listen to 44 utterances (22 SVO, 22 OVS) prosodically marked with contrastive focus, and say whether the content of the sentence matched the picture shown or not. The results were compared to the performance of 19 healthy subjects.

The results showed that aphasic individuals' performance was above chance in conditions that involved sentences with the canonical order (SVO). However, they performed at chance in interpreting OVS sentences, on both contrastive focus (marked) and declarative (unmarked) conditions. Only one patient showed an above chance

performance on prosodically marked condition, but a chance performance on prosodically unmarked condition. According to the authors, the results lead to the conclusion that the prosodical properties of the utterances do not benefit Broca's aphasics in their interpretations. The results reported in Burchert et al. (2005) are amenable to Grodzinsky's (1995) analysis, under which the nature of the deficit is syntactic. The reason why the different prosodic features do not help aphasic patients is that their comprehension is agrammatic, given that they are not able to correctly interpret OVS sentences with either marked or unmarked prosody.

The same year, 2005, Raithel published her thesis in which she carried out an experiment in order to test prosodic perception abilities of aphasics and to learn whether aphasics were able to recognize intonational contours (Raithel, 2005). The departure point of Raithel's thesis was that subjects who have suffered from a brain lesion and whose language (syntax and semantics) is impaired may have problems in comprehension at a phonological level as well. Even though she focuses on aphasics' performance in prosodic comprehension, she does not reject the idea that the impairment due to the lesion may affect other aspects of language besides prosody. Since she assumed that linguistic prosody was in part processed in the left hemisphere (Heilman et al., 1984), she tested the comprehension skills on phonology of left-hemisphere-damaged aphasics (twenty Broca's aphasics and twenty Wernicke's aphasics), expecting them to perform in a significantly less successful manner than the control group (which consisted of twenty people as well). In order to prove this, she designed two experiments to find out whether they presented impaired prosodic comprehension or not. By this couple of experiments, she attempted to demonstrate that aphasics do have problems in recognizing and distinguishing different intonational contours.

The first experiment, termed Intonation Contour Recognition Screening (ICRS), was designed to find out how well aphasic subjects recognize intonation contours. Twelve short German sentences (with common words) were recorded and presented to aphasic patients, who had to decide whether the utterances sounded like a question (rising contour) or a statement (falling contour). Both types of sentences present specific syntactic properties in German; the auxiliary verb (*kann*) moves to the beginning of the utterance in questions, as example (33) illustrates, while statements always present the

SVO canonical order, as in example (34):

(33) *Kannst* du mir heute helfen?

can-2s pron-2s CL1s today help-inf

‘Can you help me today?’

(34) Die Eltern essen Suppe.

Det-n.p parents eat-3p soup

‘Parents eat soup.’

Six of the twelve tokens tested were statements and the other three were questions. Hence, statements and questions presented their typical syntactic properties exemplified in sentence (33) and (34). In addition, each type of syntactic construction was recorded with its own intonational pattern: a falling contour characterized the statements, while questions were produced with a general rising contour.

To test how much the syntactic properties of the tokens influenced the subjects’ decision, three incongruent utterances were introduced. Raithel (2005) called these sentences *queclaratives*, since they presented the syntactic properties that characterize German statements, but their F0 was manipulated in order to emulate a question-like intonational pattern. The correct answer would be that such utterances sound like a question, given that they are produced with rising contours.

The results that appear in Figure 15 show that there were no significant differences among groups, even though control subjects performed better than Broca's and Wernicke's aphasics. The only significant difference in performance concerned the *queclarative* sentences, which presented the syntactic properties of a statement and the intonational contour of a question. According to Raithel, the less successful performance is explained by the fact that these items were confusing. Broca's aphasics performed below chance, that is, they judged the sentences by their syntax. However, as Raithel herself states, this experiment did not suffice to learn whether aphasics have impaired phonological abilities, since here the content of sentences acted as a “distractor”.

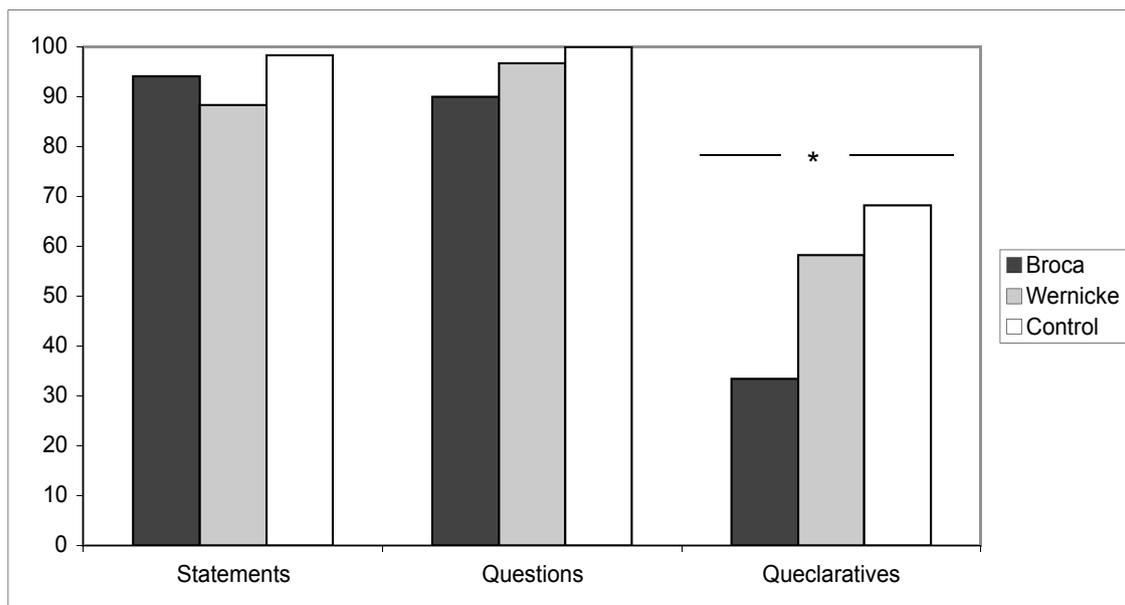


FIGURE 15. Mean results (Raithel, 2005) in percentages of success for the three groups tested in the first part of the ICRS task.

In order to stop participants from relying on syntax during the task and ignore intonational patterns, the same twelve utterances were manipulated and used in the second part of the test. The goal was to mask the content and syntax of utterances by making the words unintelligible and preserving the contour. The task was still the same: participants were asked to decide whether the utterances presented sounded like a statement or a question. Results are presented in Figure 16 and showed that there were no significant differences between the first (Figure 15) and the second test (Figure 16), even though all groups performed slightly less successful in the part which involved unintelligible sentences (masked). According to Raithel, the reason why the performance of all groups in recognizing masked statements and questions was slightly less successful than that with unmasked utterances was that participants could not rely on content, and confused utterances more easily. These results led Raithel to the conclusion that the three groups tested are able to recognize different intonational patterns. In fact, this explains the better recognition of masked *queclaratives* as rising contours (questions), once the syntactic distractor is removed. Figure 16 summarizes the mean results on the second test (with masked sentences) for the three groups tested:

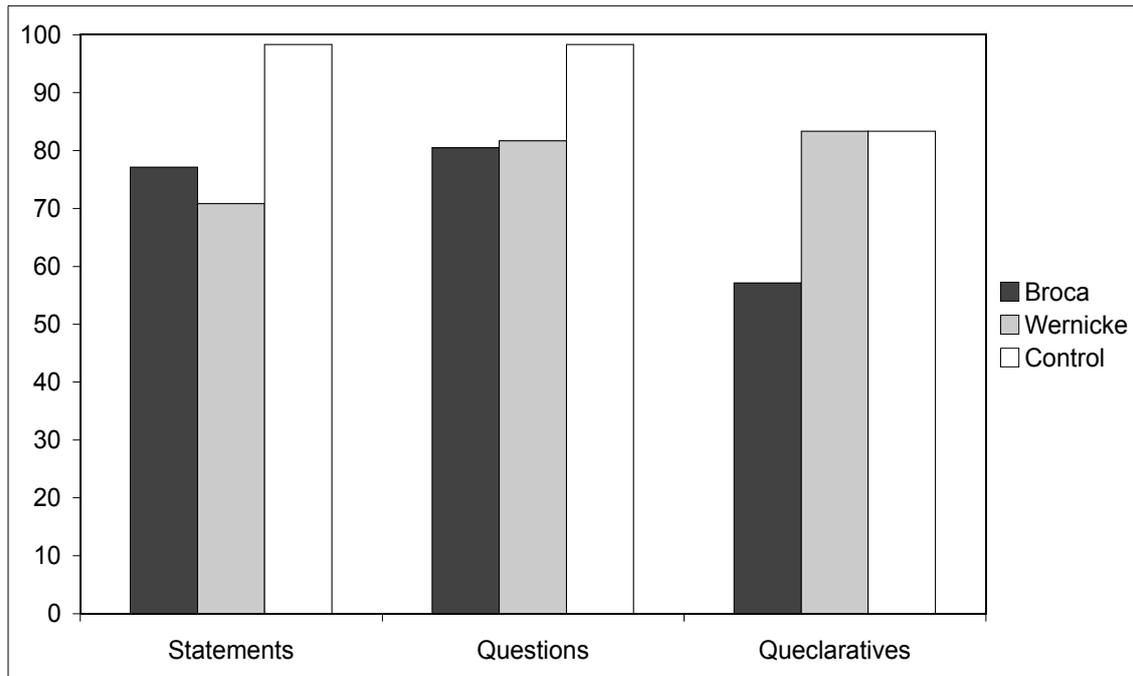


FIGURE 16. Mean results (Raithel, 2005) in percentages of success for the three groups tested in the second part of the ICRS task.

There are no significant differences between results in the first part and the second part of the experiment. Yet, the trials of the first part of the experiment did not isolate the intonational contour, so, it is impossible to know whether the participants identified the content or the intonational pattern. The inclusion of the incongruent items (*queclaratives*) was intended to reveal whether the content was dominant for intonational contour recognition. Given that the percentage of correctly recognised masked *queclaratives* increased by 25%, Raithel concluded that “as soon as the content is dominant for spoken language recognition, the listener is distracted from the intonational contour” (2005; 88). However, *queclaratives* are awkward sentences; subjects were forced to choose between the syntax or the intonational contour. This is not a realistic situation, since there are not incongruent sentences in natural speech. In fact, trusting the content rather than the intonational contour does not mean that listeners have to make a choice when they are exposed to natural spoken language. Hence, the content cannot be considered as a distractor and, actually, Raithel's results deny it: when the content is removed, the percentage of correctly recognised questions and statements decreases by a mean of 13.26%. So, these contours are better recognized when the content is not removed and, hence, content does not act as a distractor. In conclusion, the results on recognising *queclarative* contours do not suffice to establish

the degree to which participants rely on content in their identification task.

The second part of the experiment involved masked sentences, that is, manipulated utterances, which consisted of a melody without words or structure. Even though the intonational contour is isolated, this part of the experiment has an obvious disadvantage that we have pointed out above: the utterances tested are not natural spoken sentences. This fact makes the error increase, except for *queclaratives*, whose intonational contour is better recognised. Masked *queclaratives*, however, are no longer incongruent sentences and do not differ from masked questions. The distinction held makes no sense, except for comparing masked *queclaratives* with unmasked *queclaratives*, because the contour of unmasked *queclaratives* is identical to the questions' pattern. Raithel does not explain why masked questions are better recognised than masked *queclaratives*, even though they are better recognised. This result compromises the experimental design of the experiment. It can also be observed that questions were generally better distinguished on both parts of the experiment; what explains this fact, according to Raithel, is that rising contours are easier to perceive, given that they are considered marked contours.

The second experiment, which Raithel (2005) called Modified Token Test Screening (MTTS hereafter), was designed to determine whether aphasics were able to distinguish between neutral declarative and narrow focus contours. During the first part of the second experiment, termed Matching Test (MT), each utterance was presented twice consecutively (forming pairs). In six of these seven pairs, one utterance was the original recorded (a neutral declarative; i.e. *Point to the blue circle*) and the other one was manipulated in order to stress one word of the utterance (narrow focus; i.e. *Point to the BLUE circle*). The remaining pair consisted of the same utterance repeated twice (that is, two neutral declaratives). Participants were asked to say whether they thought utterances sounded different or the same.

Results are presented in Figure 17. All groups performed below chance; so, they were not able to distinguish a broad focus statement (neutral declaratives) from a narrow focus statement. Raithel postulates several hypotheses to explain the low performance on the MT. As we mentioned above, the utterances (neutral declaratives) were manipulated in order to stress one word. To do so, the acoustic modification was

previously adjusted asking some participants to say where they heard a difference. Raithel thinks that those participants perceived the differences because they were told to look for them. However, this is not a plausible explanation, because the subjects of the MT had to decide whether the utterances sounded the same or not, and this also implies looking for the differences.

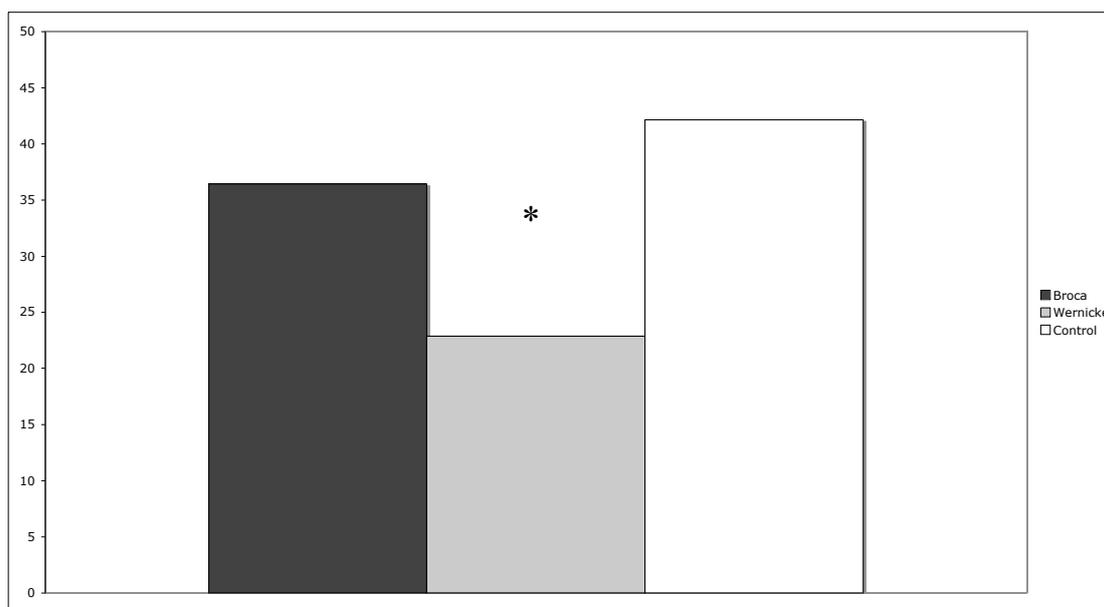


FIGURE 17. Mean results in percentages of success in the MT test (Raithel, 2005)

Another possible explanation, according to Raithel, is the same used for the ICRS test: propositional language is processed preferentially, which explains why subjects did not notice any difference between narrow focus and neutral declaratives. However, it is by the intonational contour that listeners are able to interpret correctly sentences which present the same word order. The word order of the utterances allows for more than one interpretation: it corresponds not only to a neutral declarative, but also to a narrow focus statement. The intonational contour depends on the structure of the sentence (Chomsky and Halle, 1968); so, the word order does not determine a single interpretation, ignoring the phonological properties of an utterance. This is also why the other possibility that Raithel mentions, the fact that it may be difficult “to separate the content from the form” (2005; 101), cannot be taken into consideration. Raithel is aware of that and later she argues that “it is almost impossible (for the untrained ear)” consciously to discriminate such prosodic information (2005; 118). So, according to Raithel, consciousness inhibits the ability to perceive the prosodic properties of utterances. Yet, this statement conflicts

with the literature and research on the perceptive skills of adults, who do not lose their perceptual abilities when they pay attention.

Raithel also examines the experimental design to find a reason for the low performance of participants in the MT. The author observes that the subjects may have used some answer strategies and applied the same schema of replies (i.e. considering that all the pairs sounded the same). As she states, the experimental design should be revised in order to increase the variety of items, since six of the seven pairs were different and only one was the same. However, this does not explain the fact that healthy subjects did not hear the differences. Raithel also considers the nature of the task (matching) and argues that, since it does not require a linguistic analysis (processed in the left hemisphere), the participants ignored the differences. Hence, Raithel considers that the linguistic analysis is required to identify a narrow focus statement, which she believes to be a narrow phenomenon (at a word level). Yet, a narrow focus statement consists of an intonational contour that affects the whole utterance (see section 2.4.) and not only the focused word. In addition, healthy subjects should be able to perceive the differences between two strings of sounds; the linguistic process would follow the recognition of the contour, but it is not required when perceiving sounds and distinguishing them.

Finally, Raithel mentions another possibility: participants may have not understood the task. This is a more plausible explanation, given that even healthy participants performed below chance. The choice of creating the narrow focus statements by manipulation of the original neutral declaratives could also have triggered the low performance, since only one of the prosodic parameters (amplitude, duration or F0) of the focused word were manipulated. The whole contours should be revised to make them sound like natural spoken language.

During the second part of the experiment, the so-called MTTS, subjects were told to execute task-oriented instructions (i.e. 'point to the BLUE circle'). The different degrees of difficulty concerned the length and the orders of the instructions; each subtest contained more complex structures (exemplified in Table 2).

Subtest	Example item
I	Point to the WHITE rectangle.
II	Point to the BIG blue circle.
III	Point to the blue circle and the WHITE rectangle.
IV	Point to the BIG yellow rectangle and the big green rectangle.
V	Put the yellow circle next to the GREEN circle.

TABLE 2. Example items for the MTTs reported in Raithel (2005)

As in the MT, the author created the narrow focus statements by manipulating the parameters of an original declarative sentence. Three parameters were manipulated separately in order to create different types of focus; Raithel's goal was to observe whether different kinds of focus triggered different behavioural reactions. So, three focus realization conditions were tested, depending on the parameter manipulated: pitch, duration or amplitude. Unmanipulated items configured the last type.

Raithel argues that the results presented in Figure 18 showed that all groups' performance improved in the focus condition. However, the only significant difference observed was a higher performance of Broca's aphasic patients when the duration of focused words was increased. Raithel's work lacks a structural description of contrastive focus in German, which would justify the procedure of stressing one word randomly. Moreover, as we stressed before, the intonational contour applies to the whole utterance and not only to the focused constituent. The focus realization conditions do not correspond to the narrow focus realization in spoken language; hence, the MTTs does not suffice to establish whether aphasics can distinguish contrastive focus from neutral declaratives.

Raithel (2005; 119) concludes that contrastive focus "enhances comprehension" of healthy subjects. But, as we described in section 1.3., contrastive focus structure is used to contrast new information with the presupposed belief of the listener (Rizzi, 1997), not as a cue for better comprehension of spoken language. In fact, an unimpaired speaker does not need any help to understand a neutral declarative. This is why a higher performance on tasks, which involved contrastive focus, would not indicate that participants perceived the intonational contour.

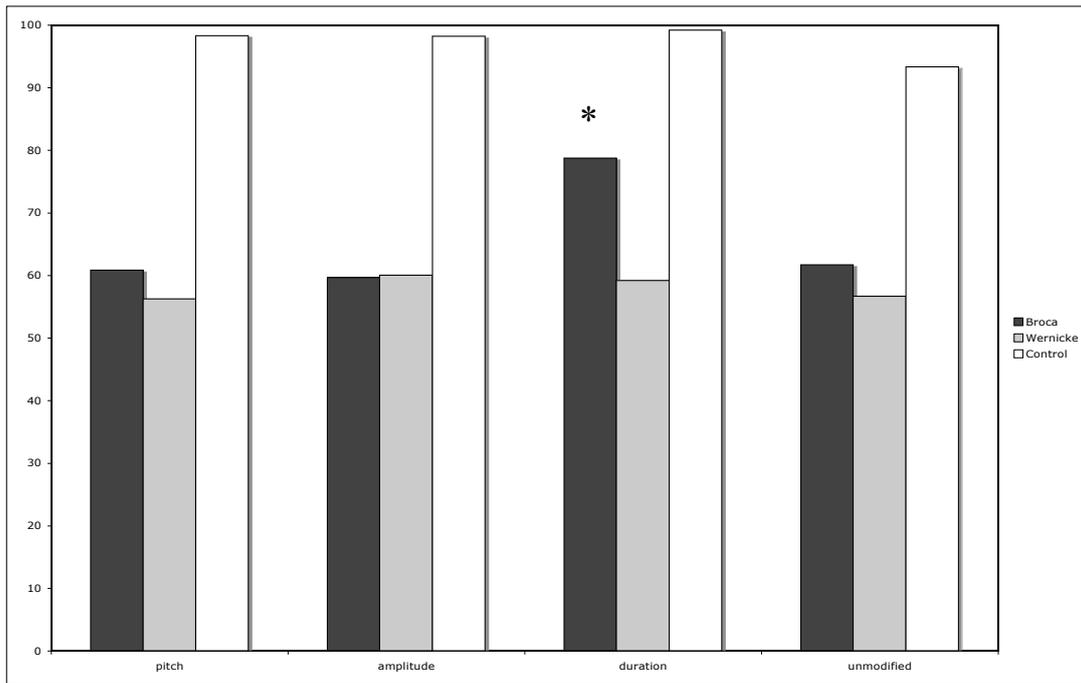


FIGURE 18. Mean percentages of success in different focus conditions of the MTTs (Raithel, 2005)

Regarding the complexity of utterances (see Table 2), what was really tested was the length and amount of information given. The instructions involve more orders in each subtest, which tested the working memory of subjects, instead of their linguistic abilities. Results in Figure 19 showed that the performance dropped when the complexity of the instructions increased.

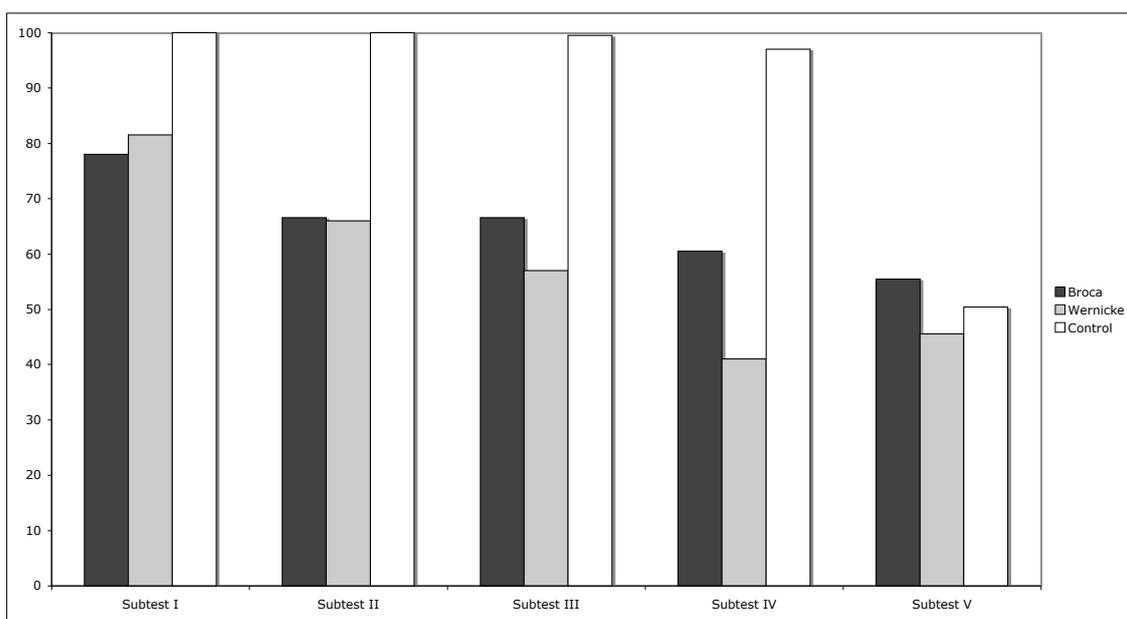


FIGURE 19. Mean results in percentages of success in different subtest of the MTTS (Raithel, 2005)

Given the above-chance performance, Raithel considered that both Broca's and Wernicke's aphasics were able to recognise the focus contour.

In conclusion, Raithel (2005) states that the differences in performance between the ICRS experiment and the MT are due to the fact that, in the former test, intonational contours affected the whole sentence, while in the latter experiment, focus affected the word. Hence, she postulates different analyses for both levels: an unconscious linguistic analysis—processed in the left hemisphere—would be necessary to process a narrower phenomenon as narrow focus in the MT, but it would not be needed in a global phenomenon as intonational contours in the ICRS experiment. According to Raithel, the results in the MTTS show that, despite the low performance on the MT, both aphasic and control subjects unconsciously perceive the realization of contrastive focus. And, despite the discrepancies manifested above, results reported in Raithel (2005) show that there are no significant differences between Broca's aphasic and control subjects' performance and, thus, that Broca's aphasics may have unimpaired prosodic abilities.

3. Experimental design

3.1. Participants

This study was conducted with twelve subjects. All of them were native speakers of Catalan. Six of these subjects were left-hemispheric CVA-patients, diagnosed with agrammatism while the other seven were age-matched control subjects (Table 4).

Agrammatic subjects were selected from the patient pool of the Sant Pau Association of Language Disorders, in Barcelona. They were all diagnosed via the Catalan or Spanish version of the Western Aphasia Battery (WAB, by Kertesz (1982)). The WAB was translated and adapted to Spanish by Kertesz et al. (1990). The subjects' age varied from 23 to 76 years old (the average was of 51.5 years old), and had different educational backgrounds. Post onset time varied from two to eighteen years. All subjects were right-handed, with the exception of S6. Patients' individual characteristics are specified in Table 3:

Subjects	Gender/age (years)	Education	Etiology	TPO (years)	Aphasia classification
<i>S1</i>	m/34	Secondary	CVA	4	Broca
<i>S2</i>	m/64	Basic	CVA	3	Broca
<i>S3</i>	m/59	Basic	CVA	6	Broca
<i>S4</i>	f/23	Secondary	Meningitis	7	Broca
<i>S5</i>	m/76	University	CVA	12	Global
<i>S6</i>	f/53	University	CVA	18	Broca

TPO = time post onset; m = male; f = female; CVA = cerebrovascular accident.

TABLE 3. Individual characteristics of agrammatic participants

More detailed characteristics of subjects are reported in appendix II.

Subjects	Gender/age (years)	Education	Education	Gender/age (years)	Control subjects
<i>S1</i>	m/34	Secondary	Secondary	m/32	<i>C1</i>
<i>S2</i>	m/64	Basic	Basic	m/67	<i>C2</i>
<i>S3</i>	m/59	Basic	Basic	m/58	<i>C3</i>
<i>S4</i>	f/23	Secondary	Secondary	f/24	<i>C4</i>
<i>S5</i>	m/76	University	University	f/78	<i>C5</i>
<i>S6</i>	f/53	University	University	m/56	<i>C6</i>

TABLE 4. Age and educational background of agrammatic and healthy participants

3.2. Methodology

A trial consisted of the auditory presentation of the same sentence twice, either realized with identical or different intonational contours. The subject's task was to listen carefully and decide whether the sentences forming a pair sounded alike or different. To do so, they were asked to press the red key, if they thought the sentences to be the same, or the green key, if they thought the sentences to be different. Colours were used instead of normal keys to ease the task, since several patients were not usual computer users. They were not asked to identify the different contours or to explain their decision.

The task with agrammatic patients was conducted in a quiet room of the Sant Pau Association of Language Disorders, in Barcelona. All the experiments with nonagrammatic patients were conducted at their homes. Prior to the task, the experimenter interviewed the participants to collect relevant personal information (age, educational background, etc.) for the selection of subjects and the interpretation of results. Then, the task was carefully explained to participants. They were told to focus on the melody (intonation) and not to worry about the content or the structure. In addition, some trials were presented as examples before running the experiment, in order to assure that the participant had understood the task. Sessions did not last more than thirty minutes.

The experiment was run on a laptop, using the free software PsyScope developed at Carnegie Mellon by Cohen, Flatt, MacWhinney and Jefferson (<http://psy.ck.sissa.it/>). To reproduce sound with a good quality, external loudspeakers were used. The volume was set up at each subject's will. There were no limitations of time, each trial was activated automatically 3 seconds after the subject had pressed a key. Both the response and the reaction time were recorded.

3.3. Materials

Stimulus materials consisted of 32 pairs of sentences, that is, a sum of 64 sentences forming pairs. Each pair comprised the same sentence rendered either with identical or different intonational contours. All patients were presented with the same pseudorandom order of stimuli, which had different experimental conditions (see Table 5). Eight pairs of 'yes-no questions vs neutral declaratives' were introduced as control items. The remaining stimuli belonged to six different experimental conditions; three groups were formed by pairs with the same intonational contour, and the other three consisted of pairs of sentences whose intonational patterns differed. Table 5 summarizes the different experimental conditions tested:

Experimental conditions	Number of trials (reversible/nonreversible)
1. interrogative vs declarative (control)	8 (4/4)
2. declarative vs declarative	4 (2/2)
3. topic vs topic	4 (2/2)
4. focus vs focus	4 (2/2)
5. focus vs declarative	4 (2/2)
6. topic vs declarative	4 (2/2)
7. focus vs topic	4 (2/2)

TABLE 5. Summary of different experimental conditions and number of trials

Different experimental conditions within pairs were arranged in random order, that is, sentences were not presented always in the same order. For example, control pairs were presented either as 'interrogative vs declarative' and 'declarative vs interrogative'. In addition, both reversible and nonreversible sentences were introduced. Even though this

condition does not affect the phonological properties of sentences, the distinction is crucial when testing agrammatics' syntactic abilities and heuristic strategies.

The semantics and grammar of sentences (commented on section 1.4.) were very simple. Very common and familiar words were used to avoid agrammatic subjects' focusing solely on content. Syntactic constructions were also very common: neutral declaratives, yes-no questions, focalized subjects and topicalized subjects. The word order of sentences, hence, was the canonical (SVO) and agrammatic subjects were supposed not to have any problem with it, according to the results reported by several studies concerning word order and agrammatism (Grodzinsky, 2000). The verbal tense used was the present simple for all trials. All these conditions were taken into consideration in order to avoid the interference of syntactic and semantic properties in their judgements and, thus, to force participants to rely only on intonational characteristics. In Table 6, there is an example for each syntactic construction and phonological pattern:

Syntactic structure and phonological pattern	Examples
Yes-no question	La mare veu el pare? det-fs mother see-3s det-ms father 'Does the mother see the father?'
Neutral declarative	El Pere toca el piano. det-ms Pere play-3s det-3s piano 'Pere plays the piano.'
Topic	La veïna, pentina el fill. det-fs neighbour comb-3s det-ms son 'The neighbour, combs the son.'
Focus	EL SENYOR, compra el diari. det-ms gentleman buy-3s det-ms newspaper 'It is he gentleman who buys the newspaper.'

TABLE 6. Examples of trials

Trials were recorded separately in a radio studio, while pairs were formed using Audacity software (<http://audacity.sourceforge.net/?lang=es>). A native Catalan-speaker

(male) read the trials at a normal reading speed and produced the various intonational contours tested which are analysed and described in section 2.4. of the present study.

For further information, see appendix I. To hear the recorded tokens, see appendix IV.

3.4. Experimental design

The experiment was designed considering the few antecedents (see section 2.5.) in the field. It was in part conceived as a replication to Raithel's experiment (2005), since it intends to improve her tests. However, we have only tested Broca's aphasics because the present study means to start exploring the agrammatic comprehension and establish the nature of the impairment.

The task required is, as in Raithel's MT, to say whether the pairs sound different or the same. We recorded natural spoken sentences, which removed all the problems regarding the perception of focus contours due to an inaccurate manipulation of focus. Hence, we deleted the distinction of focus according to the parameter manipulated, because it did not take into account the whole intonational contour and the production of the focus.

We used the contours that Raithel used in the ICRS (questions and statements) as control items and, in order to isolate the intonational contour and force the participants to rely on the prosodic characteristics when performing the task, the word order was neutralized; that is, each pair contained two identical sentences with the same words and word order.

Excluding the control items, we have also included the same number of identical and different pairs. Raithel's MT contained six different pairs and one identical pairs, and as she pointed out, a wider variety would make the experiment more consistent and avoid answer strategies.

4. Results, discussion and conclusions

4.1. Results

The percentages of correct responses of aphasic and control subjects are presented in Figure 20. Agrammatic participants performed correctly in 165 of the 192 trials; so, their performance is above chance (85.93% of correct responses). The percentage of errors is of 14.06%, which corresponds to the 27 wrong answers of the total of 192 items. Control subjects' performance is higher; their rate of right responses reaches 96.35%, since they failed only in 7 of the 192 trials.

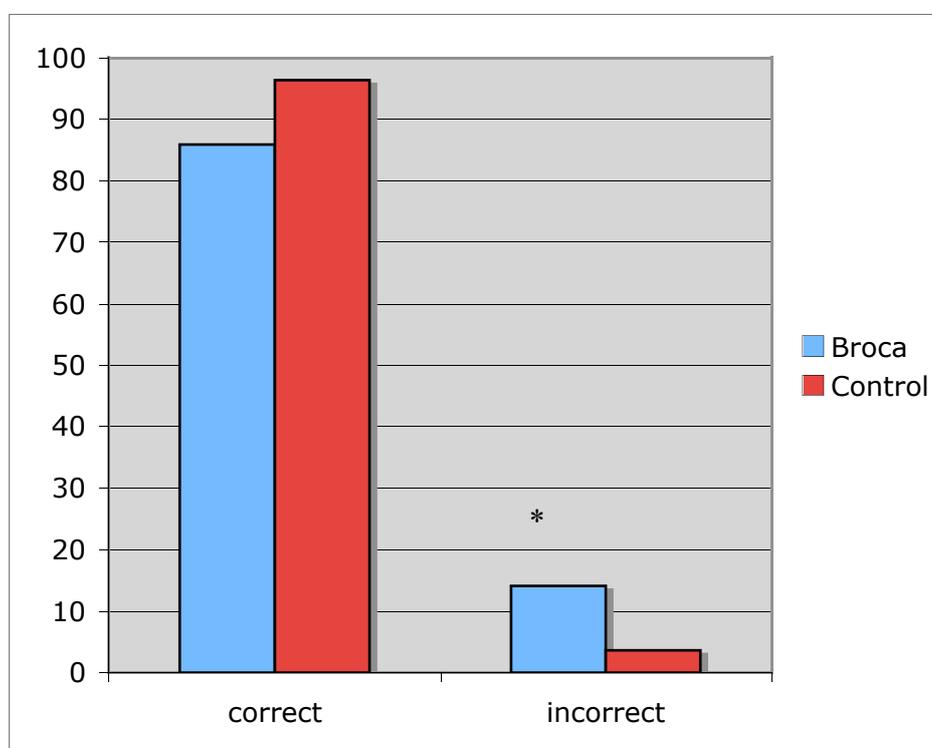


FIGURE 20. Mean percentages of success of aphasic and control subjects

A Chi-Square statistics test was performed in order to find out whether there was a statistical difference between the performance of both groups; as is reported in Table 7, the risk of finding an incorrect answer is four times higher within aphasic performance. However, the aphasics' performance is above chance, which indicates that aphasic individuals succeeded in the task.

Label	Estimate	Standard Error	Alpha	Confidence Limits		Chi-Square	Pr > ChiSq
Aphasics vs controls	1.4643	0.7083	0.05	0.0760	2.8527	4.27	0.0387*
Exp(Aphasics vs controls)	4.3247	3.0634	0.05	1.0790	17.3339		

*p < 0.05

TABLE 7. Chi-Square test for groups' performance

The percentages of correct responses of both groups by condition are presented in Figure 21. Both groups performed similarly in four conditions; three consisted of two identical items (*declarative vs declarative*, *focus vs focus* and *topic vs topic*), and the last one was the control condition (*interrogative vs declarative*). In fact, agrammatic subjects' performance coincides exactly with the healthy subjects' performance in the *focus vs focus* condition and in the *topic vs topic* condition. However, aphasic performance in conditions that involve different items worsens; this is the case of the *declarative vs topic*, the *topic vs focus* and the *focus vs declarative* conditions.

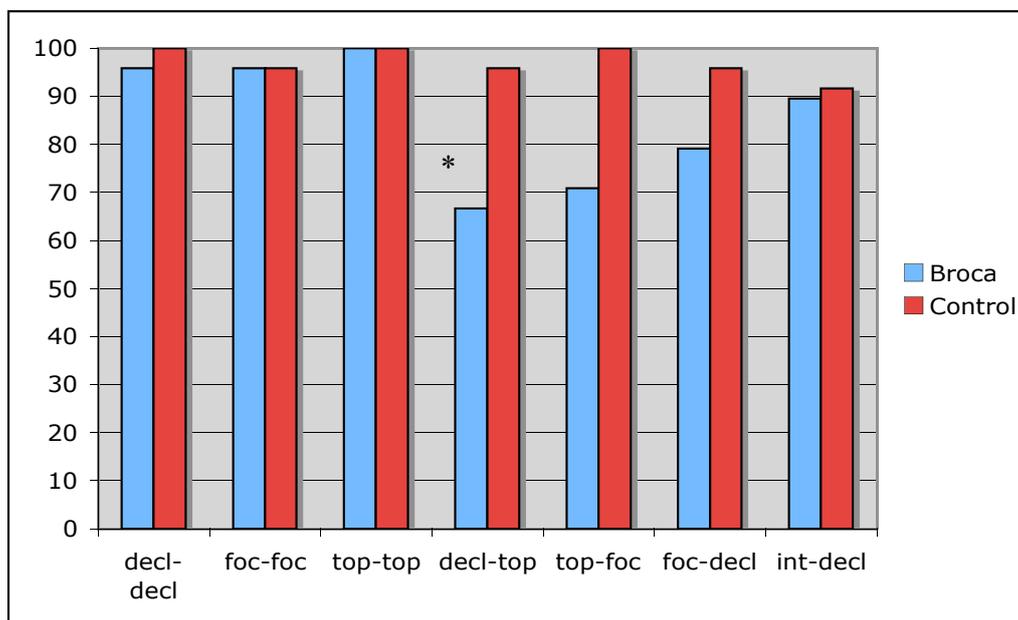


FIGURE 21. Mean percentages of success of aphasic and control subjects by condition

A Chi-Square statistics test was performed in order to find out whether there is a statistical difference between groups. A significant difference was found between the two groups' performance in *declarative vs topic* condition, in which the mean risk of

errors is eleven times higher in the aphasics' performance. The results of the Chi-Square statistics are reported in Table 8.

Label	Estimate	Standard Error	Alpha	Confidence Limits		Chi-Square	Pr > ChiSq
Aphasics vs controls	2.4423	0.9510	0.05	0.5785	4.3062	6.60	0.0102
Exp(Aphasics vs controls)	11.5000	10.9360	0.05	1.7834	74.1570		
							*p < 0.05

TABLE 8. Chi-Square test for conditions and groups

A similar difference has been observed in the *topic vs focus* condition, even though it was not possible to perform a Chi-Square test in order to find out whether there was a statistical difference between groups because there were no results (errors) from the control subjects. In the remaining five conditions, there was no statistical significant difference between aphasics and control subjects.

The distribution of aphasic errors by conditions is represented in Figure 22. Of the total errors, 54% concerns the *declarative vs topic* and the *topic vs focus* conditions, while 58% of the control subjects' errors, which are represented in Figure 23, involves the control condition (*interrogative vs declarative*). A low percentage in the aphasics' errors is found in the experimental conditions that consist of two identical items: *topic vs topic*, *focus vs focus* and *declarative vs declarative*.

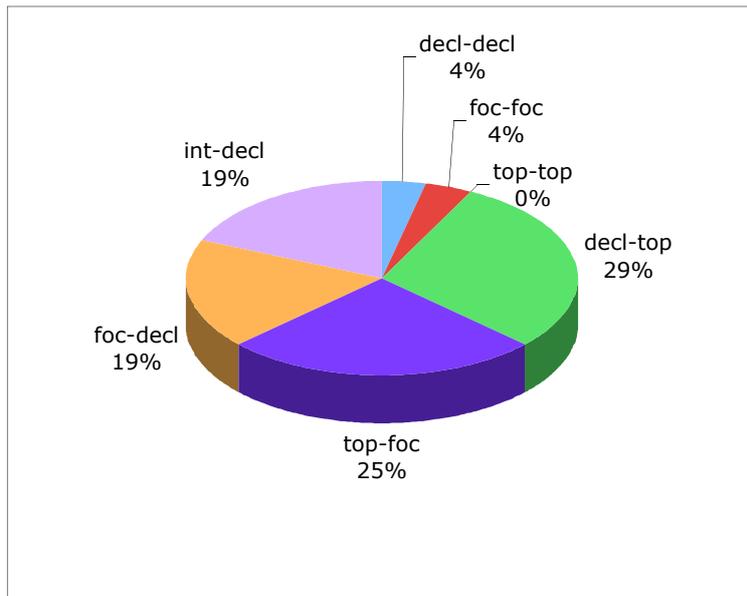


FIGURE 22. Distribution of percentages of aphasics' errors by condition

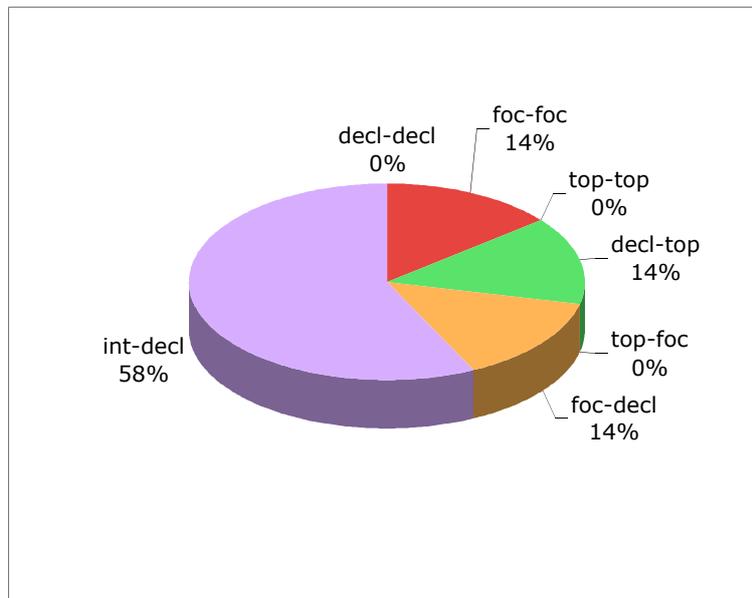


FIGURE 23. Distribution of percentages of control subjects' errors by condition

However, the aphasics' performance varies considerably across individuals, given that two subjects perform notably less successfully than the rest. In Figure 24, the percentages of aphasic individuals' correct and incorrect responses are represented. All aphasic participants performed above chance, even though S1's and S2's rate of successful responses is considerably lower than that of the others. Four aphasics' performance (S3, S4, S5 and S6) is similar to the control subject's performance, since the number of errors they made goes from 0 to 4 (the small sample of subjects does not suffice to apply a statistical test and learn whether there are significant differences

among individual performances).

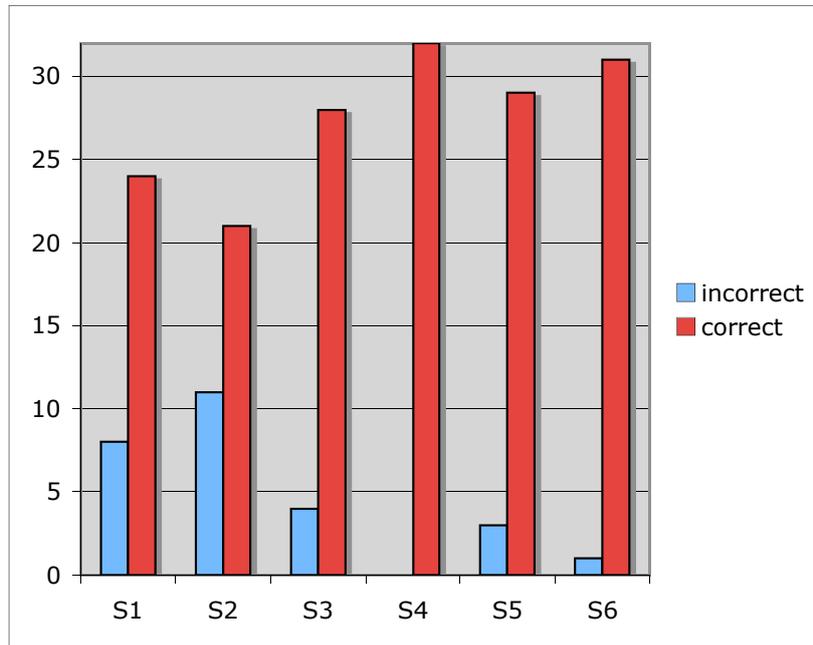


FIGURE 24. Percentages of correct and incorrect responses of aphasic individuals

As a consequence, 70% of the mistakes made by the aphasic participants correspond to the performance of two subjects (S1 and S2). That is, two subjects made 19 of the 27 total errors. The distribution of the errors among aphasic subjects is represented in Figure 25.

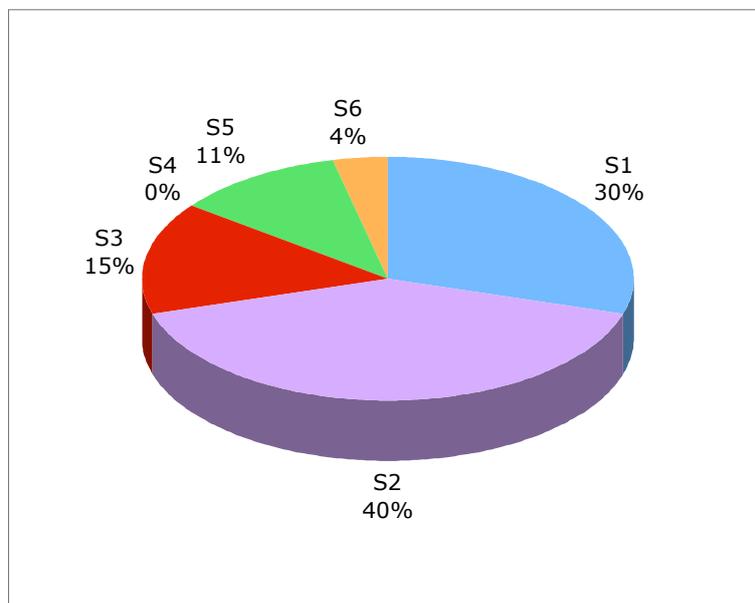


FIGURE 25. Distribution of errors by aphasic subjects

The healthy subjects' performance is much more uniform, as can be observed in Figure 26. The range of errors made goes from 0 to 3.

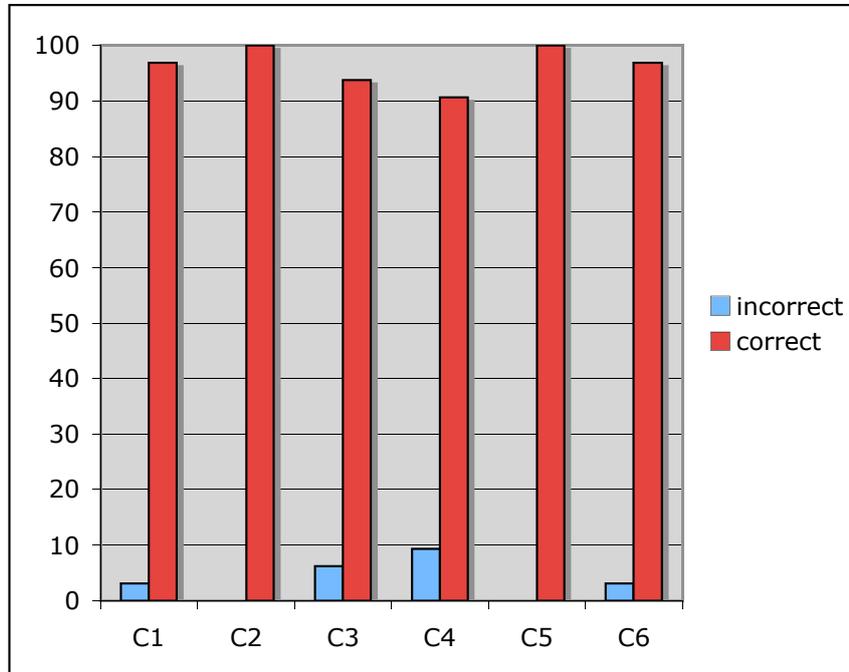


FIGURE 26. Percentages of correct and incorrect responses of control subjects

Control subjects were education- and age-matched with aphasic participants (see section 3.1.). If we compare the results by pairs (aphasic and control subject), we will see that, in general, aphasic performance does not differ from the healthy subject performance. The percentages of success by pairs are presented in Figure 27, where it can be observed that a greater difference of performance only occurs in couple 2. However, all aphasics' performance is above chance.

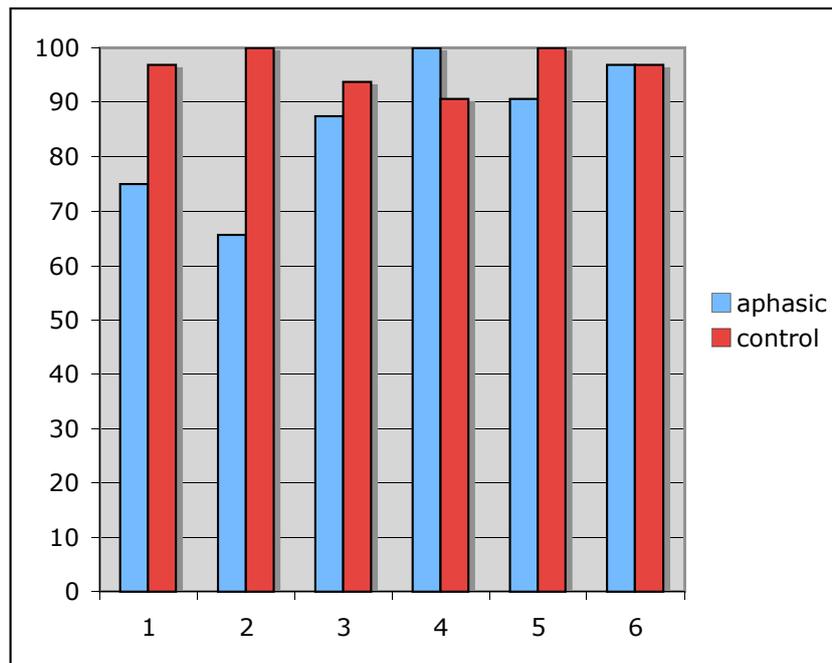


FIGURE 27. Percentages of success of aphasic and healthy individuals by couples

Reaction time was also recorded in order to see whether there were differences among groups or regarding the different experimental conditions. The results show that there is a great variability among subjects, even within groups. In general terms, aphasics tend to take more time to respond, even though this is usually due to personal circumstances, such as age or familiarity with computers. The medians of both aphasics' and healthy subjects' reaction times by condition are represented in Figure 28. However, there is no relation between a longer reaction time and the number of errors. The lower reaction time for aphasics coincides with one of the conditions in which they have been least successful (*topic vs focus*) and, at the same time, the control subjects present the higher reaction time in the same condition, although they did not make any mistake. Hence, we conclude that the reaction times relate to facts that do not concern the experimental conditions.

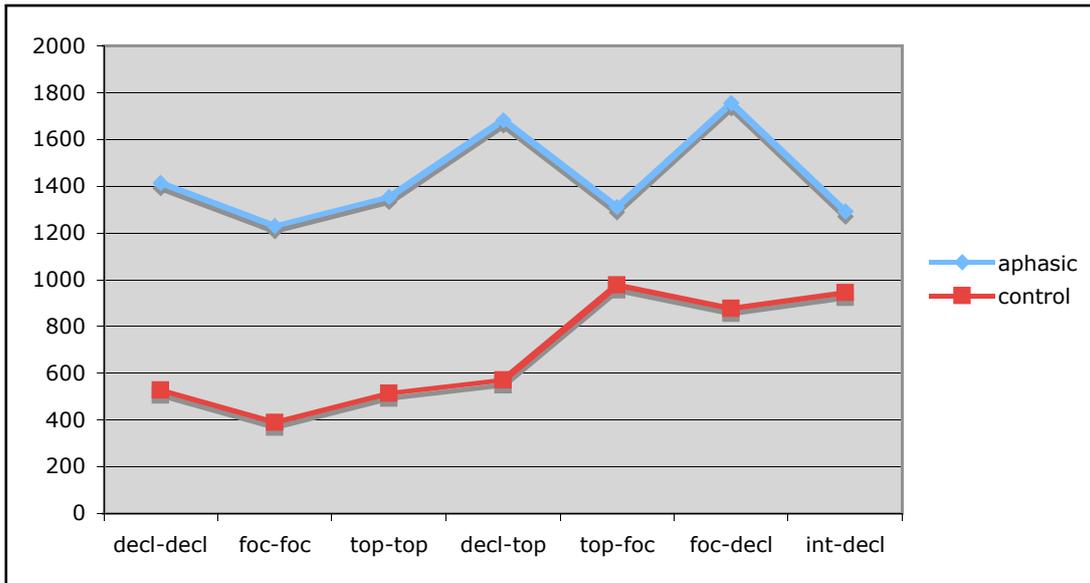


FIGURE 28. Medians of reaction times (ms) of aphasic and control groups by conditions

In Figure 29, the means of aphasics' reaction times are represented. The lower reaction times registered are those of the youngest aphasic subjects, S1 and S4, aged 34 and 23 respectively. On the other hand, the slower reaction time corresponds to the patient with more severe motor limitations (S6).

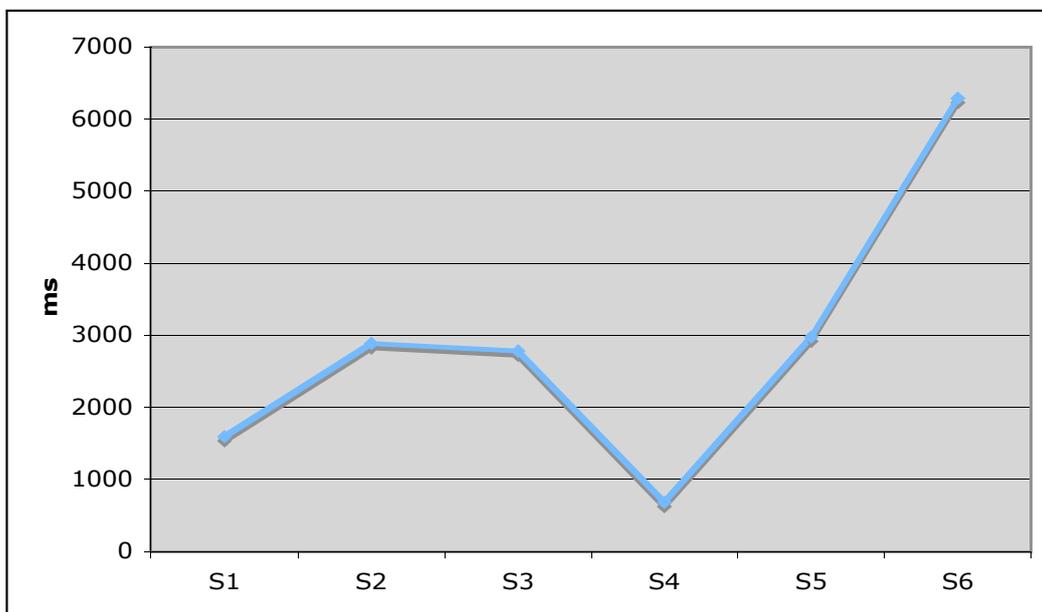


FIGURE 29. Mean reaction times of aphasic subjects

For more detailed results, see appendix III.

4.2. Discussion

The results show that aphasic individuals are able to distinguish the four intonational contours tested and, hence, that comprehension inability by agrammatic speakers must be placed elsewhere in the grammar and may be possibly due to a partial loss of syntactic processes, as Grodzinsky (1990, 2000b) has claimed. In spite of the difference between aphasics' and control subjects' performance, the aphasic individuals performed above chance in all the experimental conditions. Only one patient (S2) performed considerably less successfully than the other aphasics, but his performance is still above chance. If we consider the aphasics' performance individually and compare them to their age-matched healthy subjects, we can conclude that, in most of the cases, the performance is equivalent to healthy subjects' performance.

There is only a statistical significant difference between aphasics and control subjects in one condition (*declarative vs topic*) out of seven conditions. The performance on conditions that consist of two different contours is slightly lower than the performance on conditions that consist of two identical contours. On the *declarative vs topic* condition, the *declarative vs topic* condition, the performance is significantly less successful. However, it reaches a success rate of almost 70%, which shows that, despite the lower performance, aphasics are able to distinguish both contours. In natural situations, other factors such as the context may ease the task of recognizing each type of contour. In addition, the contours that aphasics confused share some phonological properties: they are all characterized by a rising intonation at the beginning of the utterance followed by a general falling pattern. In Figures 30 to 32, the F0 contours and prosodic labelling of a declarative, a topic and a contrastive focus are represented.

Despite the differences (see section 2.4.) that these three contours hold, the general phonological patterns of declaratives, topic and contrastive focus are pretty similar: the beginning of the contour is realized with a high tone, while the rest of the pattern consists of a general falling F0. On the other hand, the yes-no question contour contrasts sharply with them, since it is characterized by the opposite pattern, a final rising contour. In Figure 33, the F0 contour and the prosodic labelling of a yes-no question is represented, which differ from the other three represented in figures 30 to 32 and can be more easily distinguished.

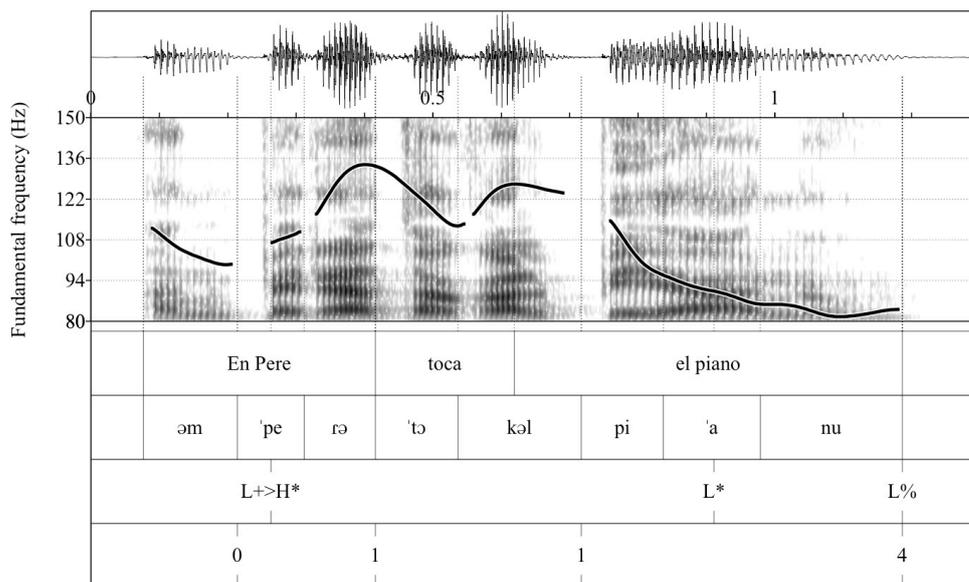


FIGURE 30. Waveform display, spectrogram, F0 contour, phonetic and orthographic transcription and prosodic labelling of the neutral declarative *En Pere toca el piano* 'Pere plays the piano'

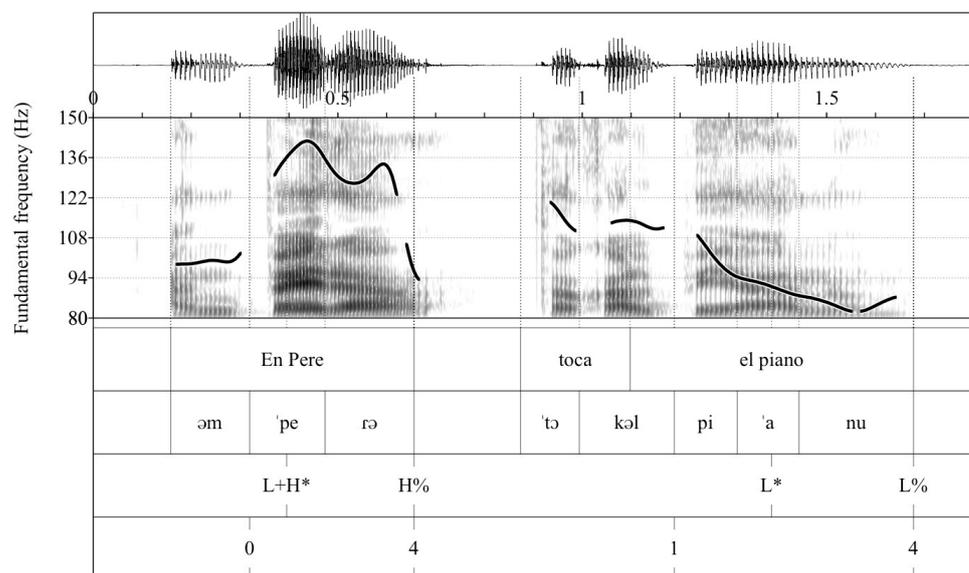


FIGURE 31. Waveform display, spectrogram, F0 contour, phonetic and orthographic transcription and prosodic labelling of the utterance (topic) *En Pere toca el piano* 'Peter plays the piano'

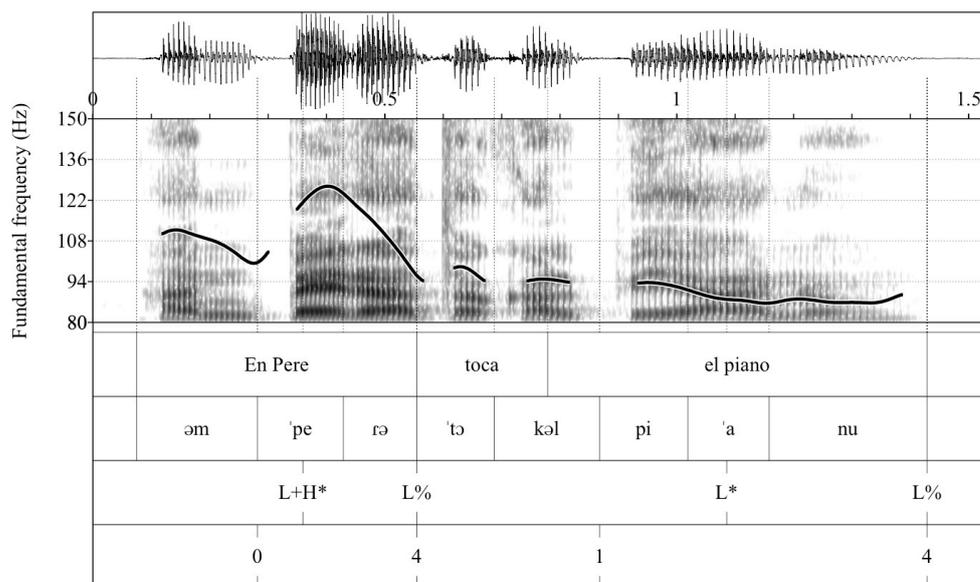


FIGURE 32. Waveform display, spectrogram, F0 contour, phonetic and orthographic transcription and prosodic labelling of the utterance (narrow focus statement) *En Pere toca el piano* ‘Pere plays the piano’

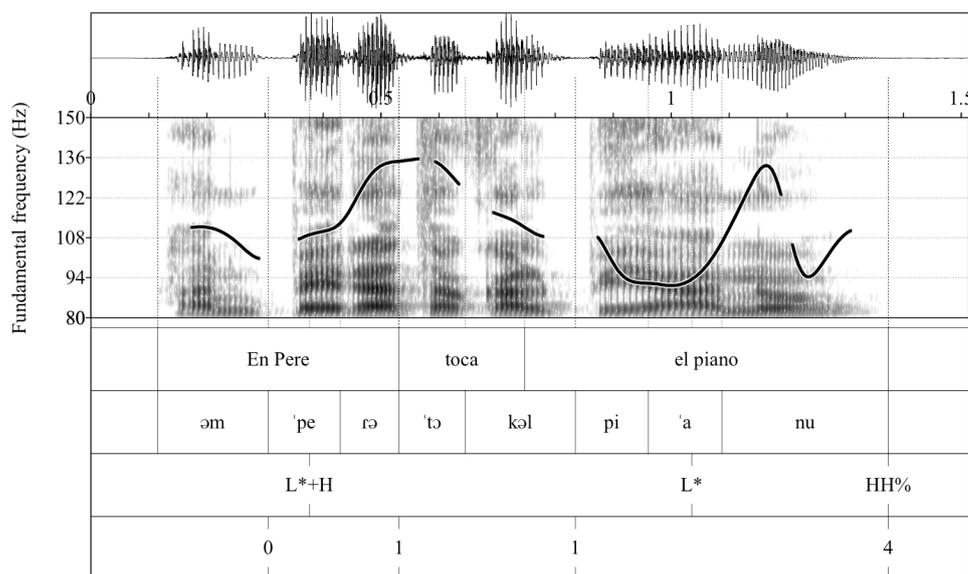


FIGURE 33. Waveform display, spectrogram, F0 contour, phonetic and orthographic transcription and prosodic labelling of the yes-no question *En Pere toca el piano?* ‘Does Pere play the piano?’

The results of the present study are similar to those that Raithel (2005) reported in her thesis (see section 2.5.). Recall that, in her Intonation Contour Recognition Screening

(ICRS) test, aphasics were asked to recognize the phonological pattern of questions and declaratives. Broca's aphasics performed above chance in recognizing the rising patterns of questions and the falling contours of declaratives.

Few studies have taken the aphasic individuals' reaction times into consideration, in order to find out whether the acquired language impairment is accompanied by processing limitations. Marinis (2008) reviews the works of this research field and reports the results of some studies (Tyler, 1985; Balogh et al., 1998; Blumstein et al., 1998 and Caplan & Walters, 2003) that relate the slower reaction times of aphasics to processing difficulties. The aim of those studies was to find out whether aphasics showed sensitivity to the syntactic information of structures that they cannot comprehend. A relation between slower reaction times and lower performance was observed, which indicated that aphasic individuals had trouble in interpreting those structures. Researchers interpreted it as an indicator of aphasic sensitivity to syntactic information, in spite of the low performance. In the present study, the reaction times recorded do not give us information about the processing of syntactic structures, but the time that subjects employ in distinguishing different intonational contours. The results show that there is no relation between the reaction times and the performance of individuals. Yet, the studies reported in Marinis (2008) stress the correlation between lower percentages of success and slower reaction times. Interpreted in the terms of Marinis, the time reactions reported in the present study may confirm what the percentages of success have shown, that is, that Broca's aphasics do not have problems at a phonological level.

The reaction times recorded do not lead to any other conclusion, since no consistent association between shorter or longer reaction times and higher or lower performances was observed. The reaction times vary a lot among individuals, even though the median of aphasic reaction time is slightly higher than that of healthy subjects. This difference may be due to external variables, such as the familiarity with the computer or the age. In addition, several aphasic patients presented motor limitations, which influences the reaction times.

Thus, the conclusion is that Broca's aphasics preserve their phonological skills and are

able to recognize different intonational contours. This conclusion is consistent with work by Grodzinsky (1995, 2000b), which describes Broca's aphasia as a partial loss in syntactic operations. The present study confirms that the disruption should concern the syntactic aspect of language, since the phonological abilities remain virtually intact.

4.3. Conclusions and further research

The present study is the first study on prosodic comprehension of Catalan agrammatics, and one of the few experiments carried out on the perception of intonational contours by agrammatic individuals. The results reported show that Broca's aphasics performed above chance and similarly to healthy subjects. These results lead us to the conclusion that Broca's aphasics are able to distinguish intonational contours. Hence, they do not show disrupted phonological abilities, and their comprehension problems regarding structures derived by movement must be due to a syntactic impairment. And, as we have already pointed out, these results are consistent with the Trace-deletion Hypothesis by Grodzinsky (1990), which describes the agrammatic comprehension as a partial loss in the ability to carry out syntactic operations.

Evidence of intact phonological abilities in Broca's aphasic individuals is provided by previous studies. Raithel (2005) carried out an experiment with German-speaking aphasics and found out that they were able to recognize different intonational contours. For Catalan, Gavarró (2005) reported indirect evidence of aphasics' sensitivity to phonological properties of utterances. The sentences tested were reversible declaratives (example (35a)), subject-contrastive focus sentences (Example (35b)) and object-contrastive focus sentences (example (35c)).

- (35) a. [El cavall] [persegueix [la girafa]]
Det-ms horse chase-3s det-fs giraffe
'The horse chases the giraffe'
- b. [EL CAVALL], persegueix [la girafa]
Det-ms horse chase-3s det-fs giraffe
'It is THE HORSE, who chases the giraffe'

- c. [LA GIRAFA], persegueix [el cavall]
det-fs giraffe chase-3s det-ms horse
'It is THE GIRAFFE, that the horse chases'

Broca's aphasics performed above chance in tasks which involved reversible declaratives and subject-contrastive focus sentences. Yet, the percentage of success of subject-contrastive focus sentences (83.3% of correct answers) was lower than that of declaratives (100% of correct answers). Aphasics showed at-chance performance on reversible object-contrastive focus sentences—which present a noncanonical order (OVS). Since the difference between (35a), (35b) and (35c) reside in the intonational contour, we would expect the same results for all of them, if the intonational contour was ignored; and this was not the case.

This evidence is also supported by several studies (including neuroimaging studies), which claim that prosody is not processed in Broca's area. Some researchers (Blumstein & Cooper, 1974; Weintraub et al., 1981 and Borod et al., 1992) claim that prosody is processed in the right hemisphere, while others (Heilman et al., 1984 and Dapretto et al., 1999) differentiate two types of prosody: emotional and linguistic prosody, which are supposed to be processed in the right and left hemisphere respectively. In addition, a large number of studies relate Broca's area to syntax; this is the case of Grodzinsky (2000b), who states that some syntactic operations are processed in Broca's area and reports some functional imaging studies that support his claim (among others, Bavelier et al., 1997; Bookheimer et al., 1993 and Stromswold et al., 1996).

The present study is a contribution to the discussion of whether Broca's aphasics have access to the prosodic information in their interpretations or not. This has been a controversial discussion, since some researchers claim that intonation does not benefit aphasics (Burchert, 2005), while others report intact prosodic abilities and the use of intonation as an enhancer for comprehension (Raithel, 2005). However, we do not consider the phonological properties of utterances as a cue to language comprehension, since they also do not function as such in unimpaired language. We assume that Broca's aphasic individuals preserve their phonological skills intact, as healthy speakers, and process prosodic information through the sensory-motor system (Hauser, Chomsky & Fitch, 2002). Their interpretation does not only consider segmental information, but also

the prosodic properties of the utterances. Thus, their phonology is either impaired or unimpaired, but it is part of language—the faculty of language—and cannot be considered as an external factor to be used as a cue for interpretation.

Further research can now explore the characterization of the syntactic impairment in agrammatic comprehension and reexamine Grodzinsky's TDH. In fact, we have proposed (see section 1.4.) to test Catalan structures that are not derived by movement and involve the left periphery, like clitic left dislocations (Cinque, 1990), which have never been tested in agrammatic comprehension. Such structures can present a noncanonical word order (OVS). According to the TDH, the aphasic individuals' performance in interpreting these base-generated structures should contrast sharply with the interpretation of structures that present a similar structure but involve movement, like contrastive focus. We can now undertake this study having established that for Catalan intonation is not disrupted in Broca's aphasia.

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APPENDIX I

I. Tokens

Conditions:

1. Yes-no question / neutral declarative

1.1. La mare veu el pare?

Det-fs mother see-3s det-ms father

‘Does the mother see the father?’

La mare veu el pare.

Det-fs mother see-3s det-ms father

‘The mother sees the father’.

1.2. La veïna pentina el fill?

Det-fs neighbor comb-3s det-ms son

‘Does the neighbor comb the son’s hair?’

La veïna pentina el fill.

Det-fs neighbor comb-3s det-ms son

‘The neighbor combs the son’s hair’.

1.3. El barret tapa el gerro.

Det-ms hat cover-3s det-ms vase

‘The hat covers the vase’.

El barret tapa el gerro?

Det-ms hat cover-3s det-ms vase

‘Does the hat cover the vase?’

1.4. La Rosa crida en Joan.

Det-fs Rosa call-3s det-ms Joan

‘Rosa is calling Joan’.

La Rosa crida en Joan?
Det-fs Rosa call-3s det-ms Joan
'Is Rosa calling Joan?'

1.5. En Pere toca el piano?
Det-ms Pere play-3s det-ms piano
'Does Pere play the piano?'

En Pere toca el piano.
Det-ms Pere play-3s det-ms piano
'Pere plays the piano'.

1.6. El senyor compra el diari?
Det-ms gentleman by-3s det-ms newspaper
'Is the gentleman buying the newspaper?'

El senyor compra el diari
Det-ms gentleman by-3s det-ms newspaper
'The gentleman is buying the newspaper'.

1.7. La nena menja patates.
Det-fs girl eat-3s potatoe-p
'The girl eats potatoes'.

La nena menja patates?
Det-fs girl eat-3s potatoe-p
'Does the girl eat potatoes?'

1.8. El nen fa deures.
Det-ms boy do-3s homework
'The boy does the homework'.

El nen fa deures?
Det-ms boy do-3s homework
'Does the boy do the homework?'

2. Declarative / declarative

2.1. La mare veu el pare.

Det-fs mother see-3s det-ms father

‘The mother sees the father’.

La mare veu el pare.

Det-fs mother see-3s det-ms father

‘The mother sees the father’.

2.2. En Pere toca el piano.

Det-ms Pere play-3s det-ms piano

‘Pere plays the piano’.

En Pere toca el piano.

Det-ms Pere play-3s det-ms piano

‘Pere plays the piano’.

2.3. La veïna pentina el fill.

Det-fs neighbor comb-3s det-ms son

‘The neighbor combs the son’s hair’.

La veïna pentina el fill.

Det-fs neighbor comb-3s det-ms son

‘The neighbor combs the son’s hair’.

2.4. El senyor compra el diari.

Det-ms gentleman by-3s det-ms newspaper

‘The gentleman is buying the newspaper’.

El senyor compra el diari.

Det-ms gentleman by-3s det-ms newspaper

‘The gentleman is buying the newspaper’.

3. Topic / topic

3.1. La mare, veu el pare.

Det-fs mother see-3s det-ms father

‘The mother, sees the father’.

La mare, veu el pare.

Det-fs mother see-3s det-ms father

‘The mother, sees the father’.

3.2. En Pere, toca el piano.

Det-ms Pere play-3s det-ms piano

‘Pere, plays the piano’.

En Pere, toca el piano.

Det-ms Pere play-3s det-ms piano

‘Pere, plays the piano’.

3.3. La veïna, pentina el fill.

Det-fs neighbor comb-3s det-ms son

‘The neighbor, combs the son’s hair’.

La veïna, pentina el fill.

Det-fs neighbor comb-3s det-ms son

‘The neighbor, combs the son’s hair’.

3.4. El senyor, compra el diari.

Det-ms gentleman by-3s det-ms newspaper

‘The gentleman is buying the newspaper’.

El senyor, compra el diari.

Det-ms gentleman by-3s det-ms newspaper

‘The gentleman, is buying the newspaper’.

4. Focus / focus

4.1. LA MARE, veu el pare.

Det-fs mother see-3s det-ms father

‘It is THE MOTHER, who sees the father’.

LA MARE, veu el pare.

Det-fs mother see-3s det-ms father

‘It is THE MOTHER, who sees the father’.

4.2. EN PERE, toca el piano.

Det-ms Pere play-3s det-ms piano

‘It is PERE, who plays the piano’.

EN PERE, toca el piano.

Det-ms Pere play-3s det-ms piano

‘It is PERE, who plays the piano’.

4.3. LA VEÏNA, pentina el fill.

Det-fs neighbor comb-3s det-ms son

‘It is THE NEIGHBOR, who combs the son’s hair’.

LA VEÏNA, pentina el fill.

Det-fs neighbor comb-3s det-ms son

‘It is THE NEIGHBOR, who combs the son’s hair’.

4.4. EL SENYOR, compra el diari.

Det-ms gentleman by-3s det-ms newspaper

‘It is THE GENTLEMAN, who is buying the newspaper’.

EL SENYOR, compra el diari.

Det-ms gentleman by-3s det-ms newspaper

‘It is THE GENTLEMAN, who is buying the newspaper’.

5. Focus / declarative

5.1. LA MARE, veu el pare.

Det-fs mother see-3s det-ms father

‘It is THE MOTHER, who sees the father’.

La mare veu el pare.

Det-fs mother see-3s det-ms father

‘The mother sees the father’.

5.2. EN PERE, toca el piano.

Det-ms Pere play-3s det-ms piano

‘It is PERE, who plays the piano’.

En Pere toca el piano.

Det-ms Pere play-3s det-ms piano

‘Pere plays the piano’.

5.3. La veïna pentina el fill.

Det-fs neighbor comb-3s det-ms son

‘The neighbor combs the son’s hair’.

LA VEÏNA, pentina el fill.

Det-fs neighbor comb-3s det-ms son

‘It is THE NEIGHBOR, who combs the son’s hair’.

5.4. El senyor compra el diari.

Det-ms gentleman by-3s det-ms newspaper

‘The gentleman is buying the newspaper’.

EL SENYOR, compra el diari.

Det-ms gentleman by-3s det-ms newspaper

‘It is THE GENTLEMAN, who is buying the newspaper’.

6. Topic / declarative

6.1. La mare veu el pare.

Det-fs mother see-3s det-ms father

‘The mother sees the father’.

La mare, veu el pare.

Det-fs mother see-3s det-ms father

‘The mother, sees the father’.

6.2. En Pere toca el piano.

Det-ms Pere play-3s det-ms piano

‘Pere plays the piano’.

En Pere, toca el piano.

Det-ms Pere play-3s det-ms piano

‘Pere, plays the piano’.

6.3. La veïna, pentina el fill.

Det-fs neighbor comb-3s det-ms son

‘The neighbor, combs the son’s hair’.

La veïna pentina el fill.

Det-fs neighbor comb-3s det-ms son

‘The neighbor combs the son’s hair’.

6.4. El senyor, compra el diari.

Det-ms gentleman by-3s det-ms newspaper

‘The gentleman, is buying the newspaper’.

El senyor compra el diari.

Det-ms gentleman by-3s det-ms newspaper

‘The gentleman is buying the newspaper’.

7. Focus / topic

6.1. La mare, veu el pare.

Det-fs mother see-3s det-ms father

‘The mother, sees the father’.

LA MARE, veu el pare.

Det-fs mother see-3s det-ms father

‘It is THE MOTHER, who sees the father’.

6.2. En Pere, toca el piano.

Det-ms Pere play-3s det-ms piano

‘Pere, plays the piano’.

EN PERE, toca el piano.

Det-ms Pere play-3s det-ms piano

‘It is PERE, who plays the piano’.

6.3. LA VEÏNA, pentina el fill.

Det-fs neighbor comb-3s det-ms son

‘It is THE NEIGHBOR, who combs the son’s hair’

La veïna, pentina el fill.

Det-fs neighbor comb-3s det-ms son

‘The neighbor, combs the son’s hair’.

6.4. EL SENYOR, compra el diari.

Det-ms gentleman by-3s det-ms newspaper

‘It is THE GENTLEMAN, who is buying the newspaper’.

El senyor, compra el diari.

Det-ms gentleman by-3s det-ms newspaper

‘The gentleman, is buying the newspaper’.

APPENDIX II

II. Participants information.

II.A. Agrammatic subjects.

Subject	Age	Sex	Handedness	Education	Languages
S1	34	male	right	Secondary	Catalan (native), Spanish (bilingual)
S2	64	male	right	Basic	Catalan (native), Spanish (bilingual)
S3	59	male	right	Basic	Catalan (native), Spanish (bilingual)
S4	23	female	right	Secondary	Catalan (native), Spanish (bilingual)
S5	76	male	right	University	Catalan (native), Spanish (bilingual). German and French.
S6	53	female	right	University	Catalan (native), Spanish (bilingual)
S7*	55	male	right	Secondary	Catalan (native), Spanish (bilingual)

Subject	Subjects' initials	Aphasia classification	Etiology	Time post Onset (years)
S1	MM	Broca	CVA	4
S2	LL	Broca	CVA	3
S3	FM	Broca	CVA	6
S4	GM	Broca	Meningitis	7
S5	JV	Global	CVA	12
S6	MP	Broca	CVA	18
S7*	JM	Broca	CVA	2

* Subject 7 was finally excluded, because he presented auditory problems after an acoustic neuroma surgery.

II.B. Control subjects.

Subject	Age	Sex	Handedness	Education	Languages
C1	32	male	right	Secondary	Catalan (native), Spanish (bilingual)
C2	67	male	right	Basic	Catalan (native), Spanish (bilingual)
C3	58	male	right	Basic	Catalan (native), Spanish (bilingual). Italian.
C4	24	female	right	Secondary	Catalan (native), Spanish (bilingual)
C5	78	female	right	University	Catalan (native), Spanish (bilingual). French.
C6	56	male	right	University	Catalan (native), Spanish (bilingual)
C7*	47	male	right	Secondary	Catalan (native), Spanish (bilingual). French, Italian.

* Control subject 7 was excluded, because his aphasic partner (S7) presented hearing problems.

APPENDIX III

III. Corpus of data

Number and percentages of correct and incorrect responses of aphasic individuals:

Aphasic subject		Frequency	Percentages
S1	incorrect	8	25.00%
	correct	24	75.00%
	Total	32	100.00%
S2	incorrect	11	34.37%
	correct	21	65.62%
	Total	32	100.00%
S3	incorrect	4	12.50%
	correct	28	87.50%
	Total	32	100.00%
S4	incorrect	0	0.00%
	correct	32	100.00%
	Total	32	100.00%
S5	incorrect	3	9.37%
	correct	29	90.62%
	Total	32	100.00%
S6	incorrect	1	3.12%
	correct	31	96.87%
	Total	32	100.00%

Mean percentage of aphasics' correct and incorrect responses:

Mean percentage of correct responses	Mean percentage of incorrect responses
85.93%	14.06%

Mean reaction times:

Aphasic subject	Mean reaction time (ms)	Median reaction time
S1	1602.38	1524.00
S2	2880.75	1938.50
S3	2779.44	1558.50
S4	681.66	674.50
S5	2967.72	386.00
S6	6287.5	4723.50

Median and mean reaction time of aphasics:

Mean reaction time (ms)	Median reaction time
2866.57	1800.83

Number and percentages of correct and incorrect responses by condition:

Conditions		Frequency	Percentages
Declarative vs declarative	incorrect	1	4.17%
	correct	23	95.83%
	Total	24	100.00%
Focus vs focus	incorrect	1	4.17%
	correct	23	95.83%
	Total	24	100.00%
Topic vs topic	incorrect	0	0.00%
	correct	24	100.00%
	Total	24	100.00%
Declarative vs topic	incorrect	8	33.33%
	correct	16	66.67%
	Total	24	100.00%
	incorrect	7	29.17%
	correct	17	70.83%

	Total	24	100.00%
Focus vs declarative	incorrect	5	20.83%
	correct	19	79.17%
	Total	24	100.00%
Interrogative vs declarative	incorrect	5	10.41%
	correct	43	89.58%
	Total	48	100.00%

Mean reaction times by condition:

Condition	Mean reaction time (ms)
Declarative vs declarative	1897.75
Focus vs focus	2820.58
Topic vs topic	2488.79
Declarative vs topic	3144.00
Topic vs focus	3632.50
Focus vs declarative	3277.45
Interrogative vs declarative	2842.47

III.B. Control subjects

Number of errors and percentages of correct responses:

Control subject		Frequency	Percentages
C1	incorrect	1	3.12%
	correct	31	96.87%
	Total	32	100.00%
C2	incorrect	0	00.00%
	correct	32	100.00%
	Total	32	100.00%
C3	incorrect	2	6.25%
	correct	30	93.75%
	Total	32	100.00%
C4	incorrect	3	9.37%
	correct	29	90.62%
	Total	32	100.00%
C5	incorrect	0	0.00%
	correct	32	100.00%
	Total	32	100.00%
C6	incorrect	1	3.12%
	correct	31	96.87%
	Total	32	100.00%

Mean percentages of controls subjects' correct and incorrect responses:

Mean percentage of correct responses	Mean percentage of incorrect responses
96.35%	3.64%

Median and mean reaction times of control participants:

Control subject	Mean reaction time (ms)	Median reaction time
C1	1696.13	288.50
C2	1402.38	881.50
C3	1712.28	1243.00
C4	1020.25	469.50
C5	2106.47	363.50
C6	1076.03	1049.50

Median and mean reaction time of control subjects:

Mean reaction time (ms)	Median reaction time
1502.25	715.91

Number and percentages of correct and incorrect responses by condition:

Conditions		Frequency	Percentages
Declarative vs declarative	incorrect	0	0.00%
	correct	24	100.00%
	Total	24	100.00%
Focus vs focus	incorrect	1	4.16%
	correct	23	95.83%
	Total	24	100.00%
Topic vs topic	incorrect	1	4.16%
	correct	23	95.83%
	Total	24	100.00%
Declarative vs topic	incorrect	1	4.16%
	correct	23	95.83%
	Total	24	100.00%
Topic vs focus	incorrect	0	0.00%
	correct	24	100.00%
	Total	24	100.00%

Focus vs declarative	incorrect	1	4.16%
	correct	23	95.83%
	Total	24	100.00%
Interrogative vs declarative	incorrect	4	8.33%
	correct	44	91.66%
	Total	48	100.00%

Mean reaction times by condition:

Condition	Mean reaction time (ms)
Declarative vs declarative	1371.50
Focus vs focus	466.46
Topic vs topic	2119.63
Declarative vs topic	852.96
Topic vs focus	3074.58
Focus vs declarative	1273.21
Interrogative vs declarative	1429.85

