Interpretation of the Verbal Form *estar+ Past Participle* in Portuguese

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Abstract

In this paper, we propose a compositional approach for the semantic analysis of sentences in Portuguese whose main verb is a compound form constructed with the auxiliary *estar* (which partially corresponds to the auxiliary *to be* in English). We show that the identification of the correct semantic representation can be achieved easily by considering only the aspectual class of the main verb and its transitivity.

1 Introduction

In this paper, we propose a compositional approach for the semantic analysis of sentences in Portuguese whose main verb is a compound form constructed with the auxiliary *estar* (which partially corresponds to the auxiliary *to be* in English). In Portuguese[1], the auxiliary *estar* has many different interpretations when combined with a verb used in the past participle form. We identified four cases that may be illustrated by the following examples:

(1) a. Paulo estava preocupado. *(Paulo was worried)*

b. Ana estava acompanhada. *(Ana was accompanied)*

c. Pedro estava sumido. *(Pedro had disappeared)*

d. A carta estava assinada. *(The letter was signed)*

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[1]Here we discuss only the Brazilian Portuguese. Another study would be necessary to see if the model proposed in this paper applies to the European Portuguese.

In 1a and 1b, the situations that are referred coincide with the denotation of the verb. The interpretation of these sentences supposes a contextual time at which a situation obtains. In the first sentence it is the state of being worried, whereas in the second case, Ana is in the state of being accompanied. In the last two sentences, the state is not the one denoted by the main verb. It is a state that results from the action denoted by the main verb. In these cases, we say that we have a *resultative* interpretation. Note that the example 1c is roughly translated in English using the Pluperfect tense. The interesting fact here is that this form would not be translated using the auxiliary *be*.

The situations may be further distinguished by considering who is the agent (or experiencer) of the action (or state) denoted by the main verb. In 1a and 1c, the agent is the entity referred by the subject of the sentence, which is not the case in 1b and 1d. In 1a and 1c, we can identify an active voice, whereas in 1b and 1d a passive voice is used.

We will show that these examples may be distinguished by using two features: resultativity and passivity. In our computational approach, the first feature is determined by the aspectual class of the main verb. As we will see, the aspectual classes distinguish the semantics of the verbs according to how the situation they denote may be decomposed in time. For example, there is an important distinction between punctual and durative events. The second feature, passivity, relies directly on the transitivity of the main verb. More exactly, it depends on whether the verb requires a direct object or not.

In the next section, we present the aspectual classification that has been used in our implementation, inspired of Vendler [14] and Moens and Steedman [10]. Then we present briefly the Discourse Representation Theory [9], which is the formalism we adopted to represent the semantics of the sentence. Finally, we show how our computational approach produces the correct semantic representation of the sentences considered in this study. In particular, we will see how the semantic representation of the sentence can be built by combination of lambda expressions with an interpretation process controlled by lexical information.

2 Aspectual class and coercion

The notion of aspectual class used in our implementation is similar to the one presented in [10]. In short, the conceptualization of eventualities[2] forms a tripartite structure called *nucleus*. A nucleus contains a *culmination*, which is a punctual event that makes the transition between two states: a *preparatory phase* and a

[2]We use the term *eventuality* to designate facts that take place in time, without distinguishing events and states.

resulting state. Lexically, the verbs are classified according to which part of a nucleus they refer to. Five classes of eventualities are identified.

One class contains states of various kind. In our application, only the lexical states are relevant. These are the states directly denoted by the verb, like *to be worried* and *to be ill*, and *consequent states* which are the result of an event. The events of our interest are the following ones[3]:

Activities: A durative eventuality that does not have a natural culmination: to sleep, to run.

Accomplishment A durative eventuality that becomes true only when a culmination is reached: to write a report, to build a house. Thus it refers to a preparatory phase and a culmination.

Achievement: A punctual event that marks a transition between a preparatory phase and a resulting state: to arrive at home, to escape.

An important characteristic of the formalism proposed in [10] is the principle of coercion, which uses some operators to transform an eventuality of one type into an eventuality of another type. In our implementation, we use two operators PROG and CONSEQ. The first one returns the progressive state of the eventuality to which it is applied. In the forms studied here, it will be applied only to activities. The operator CONSEQ returns the consequent state. Here it will be applied only to achievements and accomplishments.

3 The semantic representation: DRT

The Discourse Representation Theory (DRT), which originated from the works of [7] and [8], is at the moment one the most promising proposals for the processing of tense and aspect. In this theory, Discourse Representation Structures (DRS) are built taking into account the anaphoric nature of tense and aspect. [9] gives a detailed description of DRS construction rules, which are presented in a top-down manner that is not easy to implement. Nowadays, compositional approaches are preferred (see for example [1], [2], [4] and [12]).

Discourse Representation Structures (DRS) are built dynamically: each sentence of a discourse is used to update the current representation. The DRS that resulted from the interpretation of the previous sentences constitutes the context used to interpret the current sentence. A DRS is a pair $\langle U, C \rangle$, where U is a set

[3]Moens and Steedman description also contains *point events*, not considered here because they are not themselves states and do not imply a resulting state.

of *discourse referents* that represent the entities denoted by the sentences of the discourse, and C is a set of conditions on the referents contained in U. The set U is the *universe* of the DRS. Usually a DRS is drawn as a box with two compartments. Consider for example the following discourse:

(2) Yesterday John went to the office. Mary was reading. He talked to her.

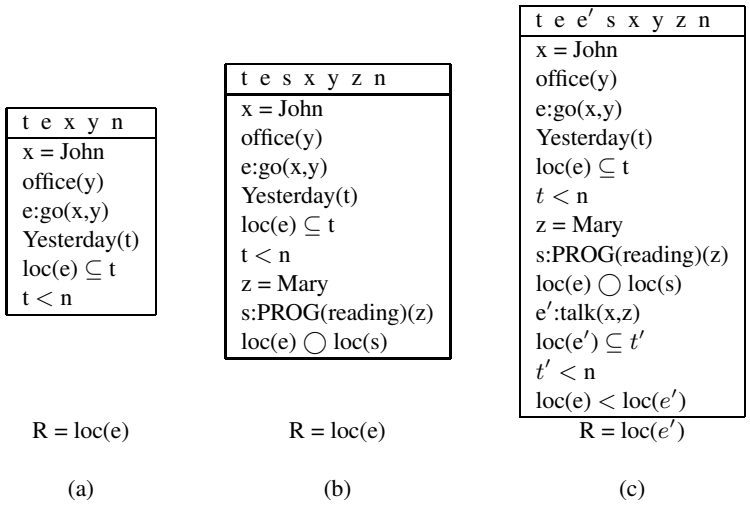


Figure 1: Interpretation of the discourse (2).

The interpretation of this discourse starts with an empty DRS. After the interpretation of the first sentence, the DRS is expanded by the addition of five discourse referents and six conditions (Figure 1a). The referents x and y represent John and the office, respectively. The referent e represents the event of going to the office. Two referents n and t are used to denote the time of speech and a temporal localizer of the event, respectively.

In DRT, an eventuality is always introduced together with a temporal localizer. When an event is introduced, it is temporally included in the temporal localizer. This is represented by the condition $\text{loc}(e) \subseteq t$, where the function loc returns the eventuality time, that is, the portion of the time axis in which the event actually takes place. This must be distinguished from the location time, which is another portion of the time axis that is used to localize this event. The temporal localizer expresses the location time of an eventuality. If the sentence does not contain any temporal adjunct, this temporal location remains unspecified.

Since the first sentence of example 2 contains such an adjunct, there is a condition specifying that the location time t is *yesterday*. According to DRT, the effect of a finite verb tense is to specify the relation between the location time and the speech time. In this example, the condition $t < n$ indicates that the location time is before the time of speech.

The second sentence, which uses a progressive form, expresses a state, represented by a discourse referent s. When a state is introduced in a DRS, it always appears with a temporal localizer. Usually a state is not included in the temporal localizer. An overlap relation is introduced.

Since the temporal localizer of the state is not specified by an adjunct, a temporal anaphora must be resolved. The time at which the described situation occurs must be found in the context. In DRT, the temporal anaphora is resolved by using a register R that is updated whenever a new event is introduced. When a new event e is introduced in the DRS, two things happen. First, a relation $x < \mathrm{loc}(e)$ is introduced in the DRS, where x is the object contained in the register R at that moment. Second, the content of R is replaced by the new event e. When a state s is introduced, as in the second sentence of the example 2, an overlap relation $x \bigcirc \mathrm{loc}(s)$ is added in the DRS and the register R is not updated. With this process, only events make the discourse progress in time. See [11] and [13] for more details about the use of this register R.

When the second sentence of (2) is interpreted, the relation $\mathrm{loc}(e) \bigcirc \mathrm{loc}(s)$ is included, since at that moment the register contains the event e. The resulting DRS is illustrated in Figure 1b. Let us now consider the last sentence. Since it expresses a situation using a simple past form, a new event e' is introduced. But now, the relation between the new event e' and the one contained in R is a posteriority relation (see Figure 1c). As expected, the new localizer t' remains unspecified.

4 A compositional interpretation of past participles

4.1 Criteria used for the interpretation of past participles

As we have argued in the introduction, the distinction of the four semantic interpretations depends on the aspectual class of the verb that is in the past participle form and the transitivity. The contribution of the auxiliary *estar* is the same in all cases, that is, it introduces a state referent in the semantic representation.

In Figure 2 are summarized the criteria used to distinguish the semantic interpretations. These criteria have been identified after a search in the NILC corpus of Brazilian Portuguese, which contains more than 26 millions words.

	-passive	+passive
-resultative	intransitive state *Paulo estava desconfiado* *(Paulo was distrustful)*	transitive activity *Ana estava acompanhada* *(Ana was accompanied)*
+resultative	intransitive achievement *Pedro estava sumido* *(Pedro had disappeared)*	transitive achievement, accomplishment *A televisão estava ligada* *(The TV was on)* *A carta estava assinada* *(The letter was signed)*

Figure 2: Criteria for the semantic interpretation of past participles

As shown in Figure 2, if the type of the situation denoted by the verb is a state, we obtain a non-resultative interpretation, since a state does not give rise to a resulting state. A state cannot be used with passive voice because it is intransitive, that is, it does not have a direct object. In Portuguese, the verb *desconfiar* (to be distrustful) denotes a state. Consequently, the expression *estava desconfiado* expresses a state that is non-resultative and non-passive.

Activities, like the states, do not imply a resulting state, but they may appear in passive voice. An activity verb like *acompanhar* (to accompany) accepts a direct object. In our search in corpus, every verb of this class has a non-resultative passive interpretation when used in a past participle form.

Achievements only have a resultative interpretation. This is as expected, since by definition they imply a resulting state. Also, they do not have a duration, and states require a duration. If an achievement verb does not accept a direct object we have a non passive interpretation. Thus, in *Paulo estava sumido* (Paulo had disappeared), what is expressed is the resulting state of disappearing, more precisely a situation in which Paulo is hidden at some place. In *A televisão estava ligada* (the TV was on), we also have a resulting situation, but in this case the agent of the action that caused the resulting state is not denoted by the subject of the sentence. In fact, since both passive and non-passive forms are possible with achievements, the only way to identify the correct interpretation is looking at transitivity. A transitive achievement will give a passive voice. Otherwise we get a non-passive voice.

Finally, our search in the corpus showed that accomplishment verbs, like *assinar* (to sign), appear only in a passive form. This may be related to the fact that all of them are transitive.

4.2 The implementation

Our implementation, in Prolog, is inspired on the parser proposed by Blackburn and Bos in [3]. In the interpretation of a sentence, every word is associated with a lambda expression that represents its semantic contribution. We use a grammar that determines how these lambda expressions may be applied to form the final semantic representation. Each lambda expression represents a DRS partially specified. For example, let us consider the expression associated to the auxiliary *estava*, which is exactly the same as the semantics proposed in [6]:

$$\text{estava:} \qquad \lambda Q \lambda y \left(\begin{array}{|c|}\hline s_i \; t_i \; n \\ \hline t_i \subseteq s_i \\ t_i < n \\ \hline \end{array} \otimes (Q \mathbin{@} s_i \mathbin{@} y) \right)$$

The operator $\otimes$ is used to merge two DRS. Let $D_1 = \langle U_1, C_1 \rangle$ and $D_2 = \langle U_2, C_2 \rangle$, the result of the operation $D_1 \otimes D_2$ is $\langle U_1 \cup U_2, C_1 \cup C_2 \rangle$. We use the symbol @ to represent the application of a lambda expression to its argument. The contribution of the auxiliary *estar* is the introduction of a state s_i together with contextual past time t_i that is temporally included in this state. Here we will not explain how the contextual time t_i may be identified. For some insights on how this could be achieved, we refer to [5].

The fact that the state referent is introduced by the auxiliary deserves an explanation, since it may be argued that it is in the nature of the past participle to denote a state. The reason is that the auxiliary, being the one that appears in a finite form, adds some information about the temporal location and the aspect of the state. It would be difficult to do this compositionally if the state referent was hidden inside the semantics of the past participle.

The argument Q is itself a lambda expression obtained from the interpretation of the main verb with its complements. As we will see later, the DRS represented by Q contains a description of an eventuality whose nature (state or event) is unspecified. Here the eventuality expressed inside Q will be identified with the state s_i. The DRS represented by Q has another unknown element, which is an argument of the predicate it contains. It is identified with the variable y, which will be further specified when the subject of the sentence will be considered. To see more clearly how it works, let us consider the interpretation of the sentence *João estava olhando Maria (João was looking at Maria)*. First, let us see the result of the interpretation of *olhando Maria*:

$$\text{olhando Maria:} \qquad \lambda S \lambda x \begin{array}{|l|}\hline m \\ \hline S : \text{PROG(olhar)}(x, m) \\ m = \text{Maria} \\ \hline \end{array}$$

Note that the predicate form *olhar(x,m)*, which denotes an activity, has been transformed in a progressive state by means of the operator PROG. The variable S represents the state referent to be identified. Combining the semantics of *estava* with the semantics of *olhando Maria*, we get the reduction illustrated in Figure 3.

$$\lambda Q \lambda y \left(\begin{array}{|l} \hline s_i \; t_i \; n \\ \hline t_i \subseteq s_i \\ t_i < n \\ \hline \end{array} \otimes (Q \mathbin{@} s_i \mathbin{@} y) \right) \mathbin{@} \lambda S \lambda x \begin{array}{|l} \hline m \\ \hline S : \text{PROG(olhar)}(x, m) \\ m = \text{Maria} \\ \hline \end{array} \Longrightarrow$$

$$\lambda y \begin{array}{|l} \hline s_i \; t_i \; n \; m \\ \hline t_i \subseteq s_i \\ t_i < n \\ s_i : \text{PROG(olhar)}(y, m) \\ m = \text{Maria} \\ \hline \end{array}$$

Figure 3: Interpretation of *estava* + *olhando Maria*

The interpretation of the sentence is completed with the semantics of *John* applied to the expression that results from the interpretation of *estava olhando Maria* (see Figure 4). The referent t_i is the contextual time that is contained in the register R, as explained previously in section 3.

$$\lambda P \left(\begin{array}{|l} \hline j \\ \hline j = \text{João} \\ \hline \end{array} \otimes (P \mathbin{@} j) \right) \mathbin{@} \lambda y \begin{array}{|l} \hline s_i \; t_i \; n \; m \\ \hline t_i \subseteq s_i \\ t_i < n \\ s_i : \text{PROG(olhar)}(y, m) \\ m = \text{Maria} \\ \hline \end{array} \Longrightarrow$$

$$\begin{array}{|l} \hline j \; s_i \; t_i \; n \; m \\ \hline j = \text{João} \\ t_i \subseteq s_i \\ t_i < n \\ s_i : \text{PROG(olhar)}(j, m) \\ m = \text{Maria} \\ \hline \end{array}$$

Figure 4: Interpretation of *João* + *estava olhando Maria*

4.3 The interpretation of the past participle

We are now equipped to see how the interpretation of the past participle may result in the final semantic representation. The task is easy if we consider the effect of

the past participle as a transformation from a canonical form into another form that corresponds to one of the four cases identified earlier. To achieve this, we use lexical rules that are triggered by the aspectual class and the transitivity of the verb.

$$\lambda P \lambda E \lambda x \left(P \mathbin{@} \lambda y \boxed{\begin{array}{|l} \\ \hline \text{E: pred}(x, y) \end{array}} \right)$$

Figure 5: Canonical form of transitive verbs

The canonical form of a transitive verb, where `pred` is the predicate associated to the verb, is illustrated in Figure 5. The variable P represents the information provided by the verb's complement. The variable E will be substituted by a state or event referent, depending on the situation. For example, when the simple past tense is used, the expression will be applied to an event that is anterior to speech time, as illustrated at Figure 6. For intransitive verbs, the only difference is that the canonical form does not contain the variables P and y.

Canonical form: $\lambda P \lambda E \lambda x \left(P \mathbin{@} \lambda y \boxed{\begin{array}{|l} \\ \hline \text{E: pred}(x, y) \end{array}} \right)$

Transformed into:

$$\lambda P \lambda x \left(\lambda E \left(P \mathbin{@} \lambda y \boxed{\begin{array}{|l} \\ \hline \text{E: pred}(x, y) \end{array}} \right) \mathbin{@} e_i \otimes \boxed{\begin{array}{|l} e_i \\ \hline e_i < n \end{array}} \right) \Rightarrow \lambda P \lambda x \left(P \mathbin{@} \lambda y \boxed{\begin{array}{|l} e_i \\ \hline e_i : \text{pred}(x, y) \\ e_i < n \end{array}} \right)$$

Figure 6: Lexical rule for simple past

Let us now see the case of the non-resultative interpretation of the past participle. If the main verb denotes a state, like *desconfiar (to mistrust)*, the lexical rule does not modify the canonical form. Figure 7 illustrates the result of the application of the semantics of *desconfiar* to the expression associated to the complement *de João*. Note that the preposition *de* does not add any information in the semantic representation. Consequently, the expression associated to *de João* is exactly the same as the one associated to the proper name *João*.

We can easily verify that the combination the semantics of *estar* with the semantics of *desconfiado de João* results in the following representation:

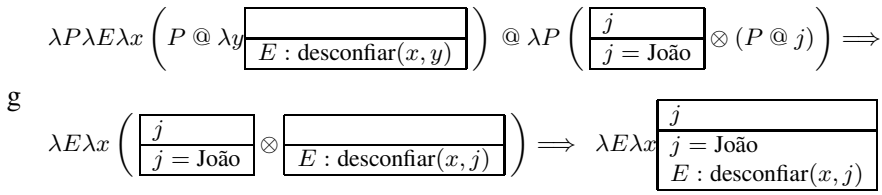
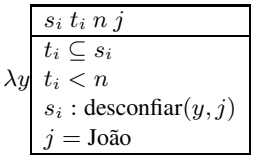


Figure 7: Interpretation of *desconfiado + de João*



As we already pointed out, when the main verb is transitive and denotes an activity, we get a passive interpretation. In this case, a lexical rule inverts the order of the arguments of the lambda expression. Also, since we have an activity, the PROG operator must be added in the representation. The transformation of the semantic of the verb *acompanhar (to accompany)* will be as illustrated in Figure 8:

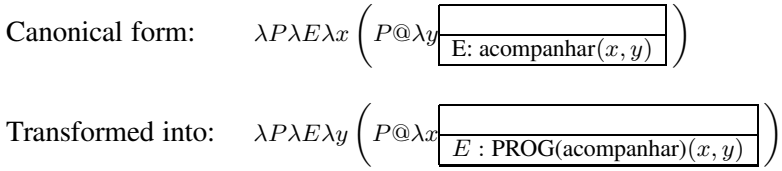
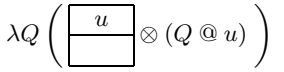


Figure 8: Lexical rule for passive non-resultative

We can see that the semantics of the complement, if there is one, would be applied to the first argument of the predicate.

If the main verb of the sentence does not have a complement, its semantic expression is applied to a dummy expression that simply adds an arbitrary discourse referent:



Thus, in our last example, before being passed as argument to the semantics

of *estava*, the expression associated with *acompanhada* must first be applied to the dummy expression, as shown in Figure 9.

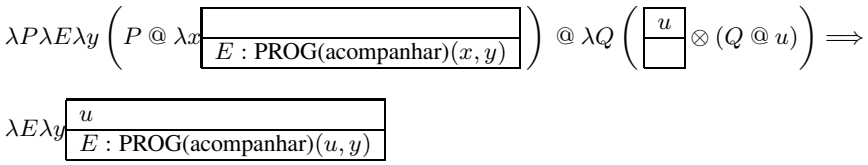


Figure 9: Interpretation of *acompanhada*

Let us now consider the interpretation of resultative past participle. As shown in Figure 2, when the verb is intransitive and denotes an achievement, we must identify the consequent state of this achievement. This is achieved using the operator CONSEQ. Also, the representation must contain an event that corresponds to the achievement denoted by the verb and which gives rise the the consequent state. Taking the verb *sumir (to disappear)* as an example, the implementation must contain a lexical rule that realizes the following transformation (the condition $e_i \supset\!\subset s_i$ indicate that the state follows immediately the event) illustrated in Figure 10.

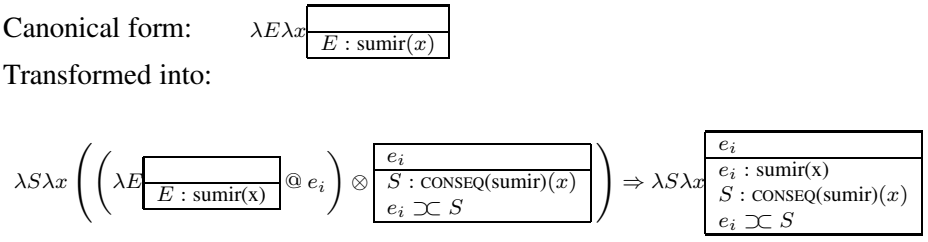


Figure 10: Lexical rule for non-passive resultative

The resulting form is combined with the semantics of *estar* and the semantics of the subject, in this order.

The lexical rule for the interpretation of the resultative passive is similar to one that is used for the non-resultative passive. The variables x and y are inverted. The only subtlety here is how to combine the new information about the resulting state with the instantiation of the variable E. To see how it is achieved, consider the transformation of the verb *assinar (to sign)* in Figure 11.

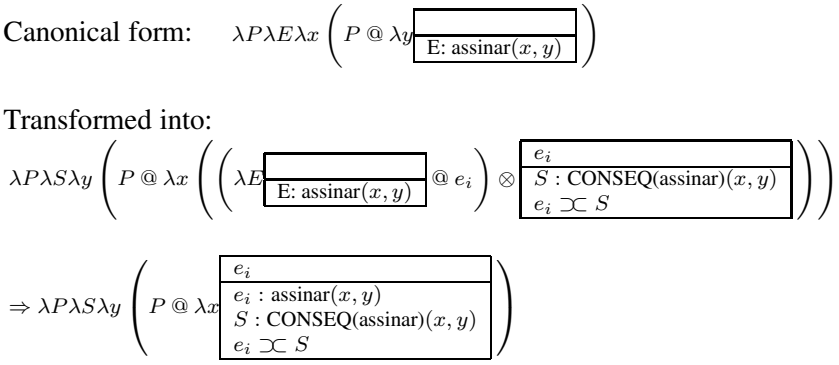


Figure 11: Lexical rule for passive resultative

5 Conclusion and future work

We have argued that, in Portuguese, the interpretation of the auxiliary *estar* followed by a past participle may result in four different semantic representations, which are distinguished by two features: resultativity and passivity. We have shown that the identification of the correct semantic representation can be achieved easily by considering only the aspectual class of the main verb and its transitivity. Our approach is compositional and is compatible with the interpretation of the progressive proposed in [6].

But our contribution is not limited to computational considerations. We also provide an linguistic account that has never been proposed before. In fact, we have not found any study describing in details the semantics of the past participle when combined with the auxiliary *estar*.

In a future work, it will be essential to test our classification with more linguistic data. An exhaustive study of verbs must be realized to validate our model. Also, it would be interesting to see how it can be adapted to other languages like French and English. Finally, we must be aware that the work presented here is only a first step in the very exciting task of implementing the interpretation of all verbal forms that may exist in Portuguese. Our appproach presented is relatively simple and concerns a limited set of the Portuguese language, but has the merit of being entirely implemented. The implementation of tensed DRT is not a simple task, and we are not aware of any compositional implementation available at this moment. We are now working on the extension of the grammar, in which other verbal forms are included together with temporal modifers, in Portuguese and English.

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