

## An Experimental study on the processing of two-clause sentences

*Um estudo experimental sobre o processamento de sentenças de duas orações*

Sara dos Santos Ribeiro 

Universidade Federal do Rio de Janeiro - UFRJ – Rio de Janeiro – Brasil

---

**Abstract:** Some temporal conjunctions can express a variety of meanings on a causal-temporal dimension. By inference, a *when*-clause may indicate a cause, an event prior in time, or even an event occurring simultaneously with the main clause event (Bever & Townsend, 1970). Using a self-paced reading experiment in the program Psyscope, we crossed the independent variables connective (*when*) and position (first position – Subordinate-Main – and second position – Main-Subordinate) to test if readers focus more on the main clause than on the subordinate clause and if readers use the order-of-mention strategy to interpret two-clause sentences conjoined with *when* establishing a causal-temporal relationship. Our results showed a significant effect of both structure and position factors. The online results showed that, in general, the main clause receives more reading times than the subordinate clause and that readers spent more time reading the main-subordinate sentences. The offline results indicate that the information about the first event is easier to recall if the *when*-clause is the first clause. Thus, the subordinate-main condition presented more accuracy rates. The order of mention strategy did not seem to be used during sentence reading processing, however, the accuracy rates were higher in conditions, in which the linguistic order mirrored the occurrence order. The main-subordinate order affected the ease of late comprehension, although it eased the reading processing.

**Keywords:** Processing and comprehension; temporal connectives; when; experimental syntax; complex sentence.

**Resumo:** Algumas conjunções temporais podem expressar uma variedade de significados em uma dimensão causal-temporal. Por inferência, uma cláusula "quando" pode indicar uma causa, um evento anterior no tempo, ou mesmo um evento ocorrendo simultaneamente com o evento da cláusula principal (Bever & Townsend, 1970). Usando um experimento de leitura individualizado no programa Psyscope, cruzamos as variáveis independentes conectiva (quando) e posição (primeira posição – Subordinada-Principal – e segunda posição – Principal-Subordinada) para testar se os leitores focam mais na oração principal do que na oração subordinada e se os leitores usam a estratégia de ordem de menção para interpretar frases de duas orações conjuntas ao estabelecer uma relação causal-temporal. Nossos resultados mostraram um efeito significativo dos fatores de estrutura e posição. Os resultados online mostraram que, em geral, a oração principal recebe mais tempo de leitura do que a oração subordinada e que os leitores gastam mais tempo lendo as frases principal-subordinadas. Os resultados offline indicam que as informações sobre o primeiro evento são mais fáceis de serem recuperadas se a cláusula "quando" for a primeira cláusula. Assim, a condição subordinado-principal apresentou maiores índices de acerto. A estratégia de ordem de menção não pareceu ser utilizada durante o processamento da leitura de sentenças, porém, as taxas de acerto foram maiores em condições em que a ordem linguística espelhava a ordem de ocorrência. A ordem principal-subordinada afetou a facilidade de compreensão tardia, embora tenha facilitado o processamento da leitura.

**Palavras-chave:** Processamento e compreensão; conectivos temporais; quando; sintaxe experimental; frase complexa.

---

### Introduction

Studies have shown that *when* has polysemic meaning: One of its inferred meaning is causality (Bever & Townsend, 1979), as in sentence (1):

(1) The glass broke *when* it fell.

The event in the adverbial *when* clause indicates the event cause in the main clause. In this sentence, the connective *when* can be replaced by *because*, which indicates the cause of the following event (effect), as well as *after*, which indicates an event that happened prior to another (Moens & Steedman, 1987; Musan, 2002). Similar to temporal sentences with *before* and *after*, the *when* clause can be placed in final position or initial one, as in (2):

(2) *When* the glass fell, it broke.

In sentence (2), the linguistic distribution of the events reflects the chronological mental representation of the events, which is cause-effect. Diversly, in (1), the events are distributed in reverse order. Thus, the *when* sentence also allows us to reorder the clauses to display events in chronological or reverse order. In this sense, we will manipulate sentences containing *when* indicating a temporal-causal relation between clauses to verify what eases or hinders processing and what strategies comprehenders use to interpret these constructions. We designed a self-paced reading test using the program Psyscope to investigate the processing and comprehension of two-clause sentences conjoined with *when*.

## 1. Theoretical framework

### 1.1 The *when*-clause

Connectives can establish more than one relationship depending on the affairs depicted in the sentence (Bever & Townsend, 1979). The temporal connective *when* commonly expresses simultaneity (Townsend & Bever, 1978; Givón, 1990). Clark (1971) proposed a set of components to represent temporal connectives. These components are +Time, the features +Simultaneous or –Simultaneous and the features +Prior or –Prior, organized hierarchically and

they are established according to the relation among the events in the sentence. In sentence (3), for example, the representation of *when* would be [+ Time, + Simultaneous]:

(3) The phone rang *when* Sue got home.

As we can see, the sentence two events happened at the same time. By the time the phone rang, Sue got home, then, we infer that the two events occurred simultaneously. The relation expressed by *when* implies that the event in the main clause and the event in the adverbial clause overlap in their realization (Cristofaro, 2003; Givón, 1990).

However, the temporal connective *when* can express more than just simultaneity. Some literature has shown that *when* can also infer a prior event (Moens & Steedman, 1987; Musan, 2002), like in sentence (4a); a cause (Bever & Townsend, 1979) like in sentence (5a); and a condition (Hall & Caponigro, 2010), like in sentence (6a):

(4) a. *When* John left, Sue cried.

b. *After* John left, Sue cried.

(5) a. The cup broke *when* it fell off the table.

b. The cup broke *because* it fell off the table.

(6) a. *When* it rains, Jeff feels sad.

b. *If* it rains, Jeff feels sad.

As we can see, *when* in sentences (4a), (5a) and (6a) can be easily replaced by the connectives *after*, *because* and *if*, respectively, and still convey the same meaning, as shown in (4b), (5b) and (6b). In (4a), there is a sequence of events: the first event *leave* is followed by the second event *cry*, then, *when* can be replaced by *after* without any damage to the meaning of the sentence. In (5a), the *when*-clause expresses causality: the *fall off* was the cause of the cup broke. This way, *when* can be easily changed by the causal connective *because*, as we see in (5b). Finally, in (6a), the *when*-clause expresses the condition for the sadness of Jeff, then, we can replace *when* by *if*, obtaining the same meaning.

Cristofaro (2003, ch. 6) argues that *when* relations, like in (3), imply that the main and dependent SoAs<sup>1</sup> (*state of affairs*) overlap in their realization, however there are some *when* relations, in which the

overlapping is not specified. This way, observing sentence (7), Cristofaro claims that we cannot infer that the SoAs, in this sentence, took place at the exact same time, since there might have been an interval between them:

(7) *When* the Nazis came to power, Georg Grosz left Germany.

The extent of time between the two events are unknown, but we can infer that there might have been some days, or months or even years between event one *Nazis coming to power* and event two *Georg Grosz leaving Germany*. What seems to be fair to assert is that the SoAs did not overlap in their realization. Considering example (7), we can also replace the connective *when* to *after* or *because* and still obtaining a similar meaning:

(8) *After* the Nazis came to power, Georg Grosz left Germany.

(9) *Since* the Nazis came to power, Georg Grosz left Germany

The event in the subordinate clause precedes the event in the main clause, thus, the connective *after* fits perfectly, as in (8). First, the Nazis came to power and, then, Georg Grosz left Germany. In addition, we can infer that the reason (cause) why Georg left Germany was the victory of the Nazis, thus, the connective *since* replaced *when* without changing the utterance meaning. The *since*-clause expresses a causal relation, in the first event. Bever & Townsend (1979) claim that

An event that occurs prior in time to another event may be the cause of the later event, but not vice versa. Similarly, an event that occurs later in time than another may be the effect of the earlier event, and not vice versa. In other words, causes are associated with earlier events and effects and adverse effects are generally associated with later events. (Bever & Townsend, 1979, 181)

The causality relation, as we could see above, can also be expressed by the *after*-clause, as the event in this clause can be the cause of the event in the main clause, taking place prior to the other event, like in (8). This causality relation can also be expressed by *when*.

Besides establishing temporal relation between clauses, *when* predicates other meanings, rather than simultaneity, depending on the referent and organization of the events in the sentence. Moens & Steedman (1987) used the term *contingency* to refer to the notions of causality of the *when*-clause. The contingency relation between the events in the subordinate clause and the main clause has to be supported by world knowledge. They also pointed out that “a *when*-clause introduces a novel temporal referent into focus whose unique identifiability in the bearer's memory is similarly presupposed” (p. 4), arguing that temporal events well defined in memory were those expressing contingency relation.

## 1.2 The ordering of *when*-clauses

Junge, Theakston & Lieven (2015) analyzed participants' sensitivity to the ordering of new/given information and its interaction with clause order. They followed a binary given/new distinction that focuses on the discourse referent accessibility degree, proposed by Arnold et al. (2000). This binary given/new distinction focused on whether the referent was mentioned in previous discourse or not. Previous research has shown preference for the given-new ordering. Regarding clause ordering, Diessel (2004) shows the main-*when* order preference. Junge et al. (2015) used an act-out experiment to test children (3 and 5 years old) and adults' comprehension of *when*-clauses. According to the *corpus* data, before 4 years old, children tend to place adverbial clauses in final position, which means that until 4;0, what guides clause ordering is processing factors. After this age, discourse-pragmatic factors such as givenness and newness become quite active.

Participants heard prerecorded stories from a speaker and had to act-out what they had just heard. They should act out one action at a time, to avoid ambiguous interpretation. All the verbs in the experiment were presented intransitively, as shown in example (10) below. To perform the task, participants used animal hand puppets and additional objects.

Experimental sentences were organized in main-subordinate order, subordinate-main order and main-main order; the information structure was ordered as given-new and new-given, like in (10) example:

(10) *Look, there's a dog and a cat!!!  
The dog is pushing, he's pushing, he's pushing.  
The cat is washing, **when** the dog is pushing.* [TEST SENTENCE]

The results showed that all groups preferred to order elements following the given-new structure when performing complex sentences, when they heard a new-given structure. When exposed to new-given structure, adults changed the clause order to subordinate-main, which shows a preference for the *when*-main clause order. No effect of clause order was found in children's results, which shows they are not sensitive to clause ordering. In sum, adults are sensitive to information structure and clause ordering, while children are only sensitive to information structure.

These results corroborated previous findings, which indicate that there is preference for *when*-main order, when the *when*-clause takes a consecutive meaning. Junge et al. (2015) explanation is that participants interpreted the *when*-clause as a consecutive clause. According to Diessel (2005), conditional adverbials appear in preposed position around 73% of the time. Thus, depending on the interpretation of the *when*-clause, the preferred distribution of clauses will change in the sentence. In addition, the initial position of the *when*-clause provides context and establishes a link to the following main clause.

### 1.3 The ordering of other temporal clauses

As we mentioned above, very frequently, temporal connectives are used to describe events both in chronological and reverse orders because temporal adverbial clauses are flexible (Diessel, 2005; Bever & Townsend, 1979) so, they can follow the main clause, as in (1) or be followed by it, as in (2) examples. However, is there a preferred ordering for the main and subordinate clauses? Why do we sometimes prepose

the main clause, and sometimes we do not? Why do we order the events in their chronological order and sometimes we do not? What influences the main and subordinate adverbial clauses ordering in a complex sentence?

Along the years, researchers have demonstrated some determinant factors that motivate the clauses ordering in a complex sentence. One of the factors is based on processing. Diessel (2005; 2008) shows that it is easier to process a sentence when the adverbial clause follows the main clause, since the processing of the main clause is completed, and only after it, the processing of the subordinate clause happens. In a main-subordinate sentence, the whole sentence is processed step by step. When the adverbial initiates the sentence, the subordinate clause has to be kept in short memory and processing is complete only after reaching the main clause. Another factor that motivates the ordering of main and subordinate clauses is based on semantics. As in real world events happen in a chronological and logical order, it is said that arranging the events in an iconic order eases processing. Another factor that influences how we order clauses is accounted to discourse-pragmatics. An initial-adverbial clause functions as an ongoing discourse organization guide.

Besides these factors, some studies have shown that adverbials processing and comprehension will be facilitated, when the focus is on the sentence main clause. Smith & McMahon's (1970) studies revealed that information asserted in the main clause is more readily accessible than the one in the subordinate clause. Later, other studies (Amidon & Carey, 1972; Amidon, 1976; Duke, 1982; Ribeiro, 2017; Maia, 2018, 2019) corroborated this assumption, which led to the discussion of competing factors during adverbials processing and comprehension, more specifically, temporal adverbials. In the present study, we will investigate the syntactic factors (clause order and main clause prominence) as well as the semantic factors (order of mention vs order of occurrence).

## 2. Methodological Framework

The current experiment presents a within-subjects comparison of initial-when sentences and final-when sentences in English. The aim is to verify what motivations ease or hinder sentence processing and comprehension. For this experiment, we constructed sentences, in which the connective *when* established a temporal-causal relation between clauses.

**2.1 Methods**

We hypothesize that structuring readers benefit from computing the syntactic structure (MAIA, 2018; 2019), then, they focus more on the main clause than on the subordinate ones. This way, the main clause information is more prominent in working memory. This is a syntactic processing hypothesis, which we will call *The Main Clause Hypothesis* (Smith & McMahon, 1970; Ribeiro, 2017). If this is true, the main clause will present longer reading times than the subordinate clause, no matter its position in the sentence. Besides that, when the main clause is more prominent, the event of this clause is easier to remember (Smith & McMahon, 1970, Duke, 1982). This way, we predict that in the conditions in which the main clause is the last clause, if the reader focus more on this clause, both reading times and response times (RTs) will be longer, since the reader will need to mentally go back to the sentence-initial *when*-clause to retrieve the semantic relation the connective established with the main clause. The final answer accuracy rates of the subordinate-main condition will be shorter if the main clause information is retained longer.

It is argued that main-subordinate sentences are easier to process than subordinate-main sentences (Diessel, 2005; Blything et al, 2015, among others), however, our assumption is that it is only true if the sentence is iconic, which means the linguistic representation of the events reflects their real order. The other hypothesis we aim to test is that adult readers (even those, who are structuring readers) use the order-of-mention strategy (a strategy used by children, proposed by Clark, 1971; Diessel, 2004) to

interpret temporal sentences, when they present the events in reverse order. This semantic hypothesis we will call *The Order of Mention Hypothesis*. If this is true, the reading times of the subordinate-main clauses will be shorter, for this construction would be less costly to process than the main-subordinate conjoined by *when*. We also predict that the RTs and errors rates will be higher in the main-subordinate condition. Thus, iconic sentences will be read faster, RTs will be slower and accuracy will be higher.

To test these hypotheses, we created a self-paced reading experiment using the program Psyscope and crossed the independent variables connective (*when*) and position (first position – Subordinate-Main – and second position – Main-Subordinate), which generated a 1 x 2 design, with 2 experimental conditions as shown on table 1. The online dependent variables were reading times of the critical areas (see data analyzes below) and the offline dependent variables were reaction times and accuracy rates.

**2.1.1 Participants**

Twenty English native speakers, undergraduate and graduate students at the University of Massachusetts Amherst had normal or corrected-to-normal vision. The age range was 18-35 years old. They were all volunteers.

**2.1.2 Stimuli**

Table 1 shows the two conditions generated by crossing the variables connective and position. We created four lists with 36 sentences, 12 experimental and 24 trials.

<b>Subordinate-Main (SM)</b>	Yesterday, <i>when</i> Mary played, John sang.	Yesterday, <i>when</i> John sang, Mary played.
<b>Main-Subordinate (MS)</b>	Yesterday, John sang <i>when</i> Mary played.	Yesterday, Mary played <i>when</i> John sang.

**Table 1 – Experimental conditions.**

All the experimental sentences had two different subjects and two intransitive<sup>2</sup> verbs in the past.

The subjects of a sentence could be two different nouns or two different names. The two events of each sentence had a pragmatic relation. One event could always happen before, or after the other. The order of the events depended on which event was described in the subordinate clause. Since the connective *when* was being used as a temporal ordering connective, the event of the *when*-clause was always the first event to happen. The sentences were always plausible, no matter which event was being described first or last. This way, each sentence had two versions, as shown in Figure 1 below:

**Figure 1** – Versions of experimental sentences.

X when Y – when Y, X Y when X – when X, Y
--

**2.1.3 Procedure**

The experiment was built on the program Psyscope, on a MacBook Air 11". The experimenter brought the computer to the participants and the test was done in quiet rooms at the university. First, participants received an oral explanation about the experiment procedure. Second, they read written instructions and did the training to familiarize themselves with the task. After the training, if they had understood the task, they started doing the test. Participants read the sentences segment by segment. To call each segment, the participant pressed the space key on the keyboard. After each sentence, on the right. The program we used did not count the time of the last segment, this way, there was the question: "What happened first?". There were two possible answers, one on the left and the other on the right (Figure 3). They had to press the green key on the left to choose the option on the left, and the yellow key on the right to choose the option of the sentences. Figure 2 shows the sequence of an experimental item during the test. Each set was a different screen.

**Figure 2** – Sequence of an experimental item during the reading.

	_____
1 <sup>st</sup> Segment	Yesterday, _____
2 <sup>nd</sup> Segment	_____ when _____
3 <sup>rd</sup> Segment	_____ Mary _____
4 <sup>th</sup> Segment	_____ played, _____
5 <sup>th</sup> Segment	_____ John _____
6 <sup>th</sup> Segment	_____ sang. _____
_____	_____

**Figure 3** – Screen of the final question after reading the sentence.

What happened first?	
John sang	Mary played

**2.1.4 Data Analysis**

We analyzed the reading times of the main clause (segments 5 and 6 of SM; and segments 2 and 3 of MS), the subordinate clause without the connective (segments 3 and 4 of SM; segments 5 and 6 of MS), the connective alone (segment 2 of SM; segment 4 of MS). We also analyzed the total reading times (segments 1 to 6 of the two conditions). For the offline results, we analyzed the reaction times to answer the final question and the accuracy of answers.

**Table 2** – Analyzed segments.

Conditions	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6
SM	Yesterday,	When	Mary	played	John	sang.
MS	Yesterday,	John	sang	when	Mary	played.

For all measures, statistical analyses of variance (ANOVA) were performed using the EzANOVA program. Outliers were not part of the analysis. We used Graph Pad Prism program to perform the Chi-square  $\chi^2$  test.

### 3. Results

The results were separated into two sections, online and offline. In the online section, we will present the results of the main clause, the subordinate clause, and the connective, separately, in the conditions with *when* in the first position (SM) and the second position (MS). We will also show the comparing results of the main clause and the subordinate clause, as well as the results of the total sentence reading times. In the offline section, we will present the results of the reaction times and the accuracy of the answers.

#### 3.1 Online Results

##### Main clause

Figure 4 and Table 3 show the reading times of the main clause in the first position (M1) and in the second position (M2). The ANOVA results revealed a highly significant effect of the factor order ( $F(1,119) = 114$   $p < 0.000001$ ), indicating that the main clause in the first position of the sentence had significantly higher reading times than the main clause in the second position. Paired t-tests confirmed the significant effect ([SM]vs[MS]  $t(119)=10.70$   $p < 0.0001$ ).

**Figure 4 – Main clause reading times in milliseconds.**



MS: Yesterday, **John sang** when Mary played.

SM: Yesterday, when Mary played, **John sang**.

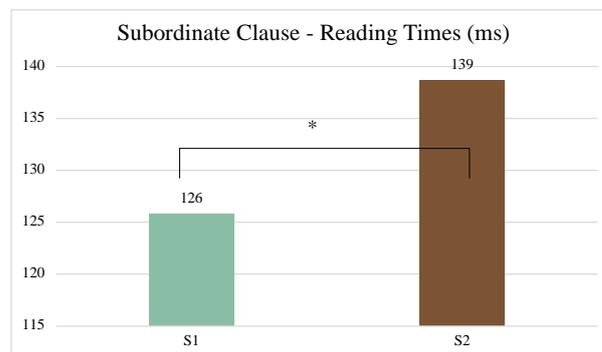
**Table 3 – Main clause reading times in milliseconds.**

Position	M1	M2
Reading times (ms)	133	182

##### Subordinate clause

Comparing the reading times of the subordinate clause in the first position (S1) and in the second position (S2), the analysis of variance showed a high main effect of order ( $F(1,119) = 22.8$   $p < 0.000005$ ). As we can see in Figure 5 and Table 4, the reading times if the subordinate clause in the second position were significantly higher than the reading times of the subordinate clause in the first position ([SM] vs [MS]  $t(119)=4.78$   $p < 0.0001$ ).

**Figure 5 – Subordinate clause reading times in milliseconds.**



SM: Yesterday, when **Mary played**, John sang.  
 MS: Yesterday, John sang when **Mary played**.

**Table 4 – Subordinate clause reading times in milliseconds.**

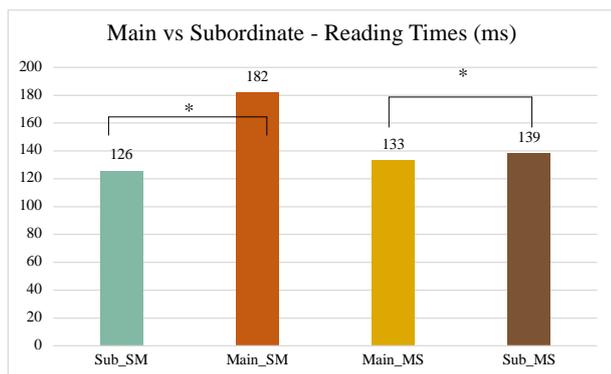
Position	S1	S2
Reading times (ms)	126	139

##### Main clause vs Subordinate clause

The results of the reading times of the main clauses and the subordinate clauses are shown in Figure 6 and Table 5. The ANOVA indicated a highly

significant main effect of the factors position ( $F(1,119) = 45.3$   $p < 0.000001$ ) and clause type ( $F(1,119) = 136$   $p < 0.000001$ ). The interaction between the two factors also showed a main effect ( $F(1,119) = 136$   $p < 0.000001$ ). Paired t-tests revealed significant differences between the reading times of the main clause and the subordinate clause in the first position and the second position. The main clause in the condition SM showed highly significant longer reading times than the subordinate clause ([Sub\_SM] vs [Main\_SM]  $t(119) = 11.83$   $p < 0.0001$ ). In the condition MS, the reading times of the subordinate clause were significantly higher than the main clause ([Sub\_MS] vs [Main\_MS]  $t(119) = 1.99$   $p < 0.0487$ ).

**Figure 6** – Main clause and Subordinate clause reading times in milliseconds.



SM: Yesterday, *when* Mary played, John sang.  
 MS: Yesterday, John sang *when* Mary played.

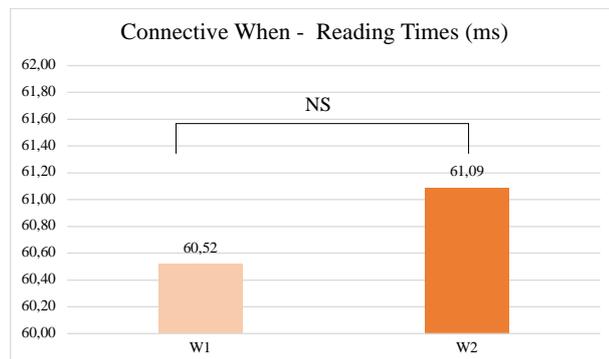
**Table 5** – Main clause and Subordinate clause reading times in milliseconds.

Clause_Condition	Sub_SM	Sub_MS	Main_SM	Main_MS
Reading times (ms)	126	182	139	133

*Connective*

In this section, we will present the results of the reading times of the connective *when* in the first clause and in the second clause of the sentence.

**Figure 7** – Connective *When* reading times in milliseconds.



SM: Yesterday, *when* Mary played, John sang.  
 MS: Yesterday, John sang *when* Mary played.

**Table 6** – Connective *When* reading times in milliseconds.

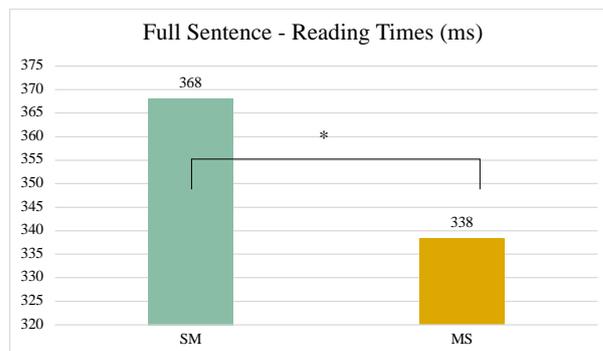
Position	W1	W1
Reading times (ms)	60,52	61,09

The ANOVA revealed no significant main effect of the factor position ( $F(1,119) = 0.259$   $p < 0.611438$ ). Paired t-tests showed that the reading times of *when* in the first clause and in the second clause have no significant differences ([First] vs [Second]  $t(119) = 0.51$   $p < 0.6114$ ).

*Full sentence reading times*

Figure 8 and Table 7 show the results of the reading times of the full sentences in the conditions SM and MS.

**Figure 8** – Full sentence reading times in milliseconds.



SM: Yesterday, *when* Mary played, John sang.  
 MS: Yesterday, John sang *when* Mary played.

**Table 7** – Full sentence reading times in milliseconds.

Conditions	SM	MS
Reading times (ms)	368	338

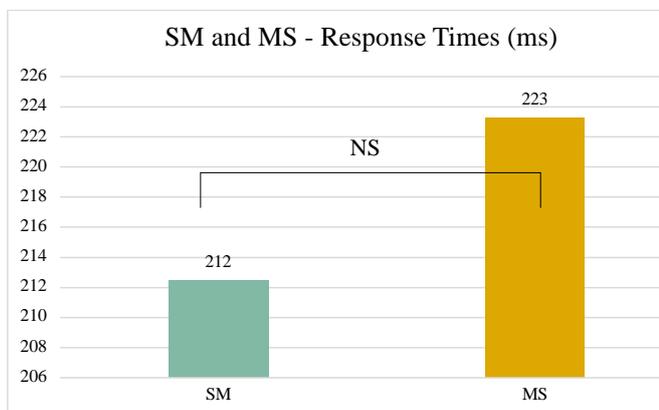
The ANOVA revealed a significant main effect of the factor position ( $F(1,119) = 58.4$   $p < 0.000001$ ). Sentences with the connective *when* in the first position (SM) had significantly longer reading times than sentences with *when* in the second position (MS) ([SM] vs [MS]  $t(119) = 7.64$   $p < 0.0001$ ).

### 3.2 Offline results

In this section, we will present the results of the response times and the accuracy rates of the final answers. The participants had to answer the question “*What happened first?*” after reading the sentences.

#### Response times

**Figure 9** – Response times in milliseconds of the conditions SM and MS.



**SM:** Yesterday, *when* Mary played, John sang.

**MS:** Yesterday, John sang *when* Mary played.

**Table 8** – Response times in milliseconds of the conditions SM and MS.

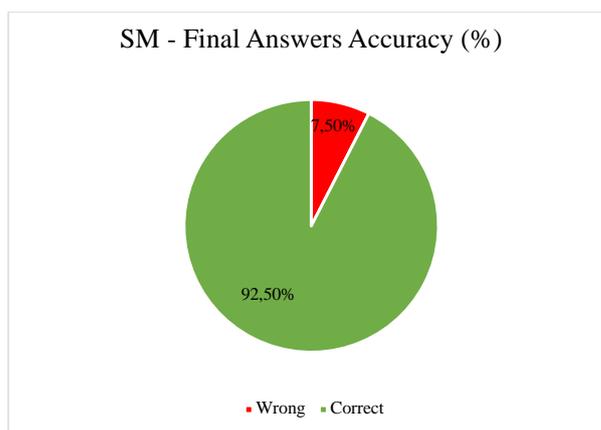
Conditions	SM	MS
Response times (ms)	212	223

The ANOVA revealed no significant main effect of order ( $F(1,119) = 3.57$   $p < 0.061119$ ). Response times in the conditions SM and MS had no significant differences ([SM] vs [MS]  $t(119) = 1.89$   $p < 0.0611$ ), as shown in Figure 31 and Table 21.

#### Accuracy rates

In this section, we will present the percentage of correct and wrong answers. In the condition in which the *when*-subordinate initiated the sentence (SM), participants had a total of 7,5% of wrong answers and 92,5% of correct answers, as represented in Figure 10 and Table 9 below.

**Figure 10** - Percentage of correct and wrong answers of condition SM.



**SM:** Yesterday, *when* Mary played, John sang.

**Table 9** – Percentage of correct and wrong answers of condition SM.

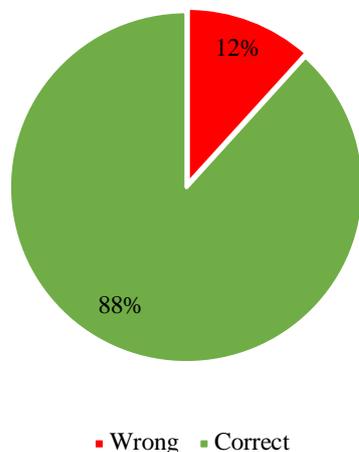
	Wrong	Correct
<b>SM</b>	7,5%	92,5%

Chi-square analyses were performed yielding the following results: Correct x Wrong ( $\chi^2 = 147.9$ ,  $p < 0.0001$ \*\*\*\*).

In the condition in which the *when*-subordinate was the second clause (MS) of the sentence, the participants had a total of 12% of wrong answers and 88% of correct answers, as shown in Figure 11 and Table 10 below.

**Figure 11** – Percentage of correct and wrong answers of condition MS.

### MS - Final Answers Accuracy (%)



**MS:** Yesterday, John sang *when* Mary played.

**Table 10** – Percentage of correct and wrong answers of condition MS.

	Wrong	Correct
MS	12%	88%

Chi-square analyses showed the following result: Correct x Wrong ( $\chi^2 = 115.5$ ,  $p < 0.0001^{****}$ ).

These results show that the condition with the *when* clause in second position was more difficult to answer (12% of errors) than the condition with the *when* clause in first position (7,5% of errors).

### 3. Discussion

Regarding the reading times of the clauses, the results showed that the last clause of both conditions had longer reading times. This reading pattern might indicate a wrap-up effect, which happens when the final parts of the sentence receive more reading times. We believe these results are due to the technique used in the experiment. However, we still have interesting data to discuss.

The reading times of the main clause in the last position were much longer than in the first position. The high cost of a subordinate-main sentence is seen in other types of subordination. It is argued that

subordinate-main sentences are more processing demanding, since they make more demands on working memory (Diessel, 2004; Blything et al, 2015). In the subordinate-main condition, right at the beginning of the sentence, the reader finds a connective and needs to bear in mind the semantic relation that the connective will establish with the following main clause. When the reader arrives at the main clause, he needs to remember the information of the subordinate clause and the relation expressed by the connective, so that he can organize the events in order to fully interpret the sentence. The computation of subordinate-main clause sentences imposes higher demands on working memory than the computation of main-subordinate clause sentences. Accordingly, our results of the SM condition indicate that the reading processing of the subordinate-main sentence costs more, which explains the longer reading times of the last clause.

The comparative results among the clause types in the condition SM revealed a much more significant result between subordinate and main clause than in condition MS. On one hand, in condition SM, the total reading times of the last clause was 182ms. On the other hand, in condition MS, the reading times of the last clause was much shorter: 139ms. These differences were statistically significant ( $p < 0.0001$ ). Thus, we believe there is a reason why the last clause had much longer reading times when it was a main clause. Besides the need of retrieving the initial semantic relation, established by the connective, the reader spent time retrieving information depicted in the previous subordinate clause. Comparing the reading times of the first clauses, t-tests revealed highly significant differences between the initial-main clause and initial-subordinate clause ( $p < 0.0001$ ). The initial-main clause had longer reading times than the initial-subordinate clause. These differences show that, in general, readers spent more time reading the sentences main clause. It might indicate some inclination to the syntactic account, which claims the main clause receives more attention than the subordinate clause, for that is syntactically and semantically main.

According to our second hypothesis, we predicted that the subordinate-main sentence, in which the linguist representation of the events matches their real order, should display lesser processing costs. In this condition, the reader would not need to rearrange the information of the events in order to comprehend the sentence. However, our results go in the opposite direction. The SM condition presented longer reading times compared to the MS condition. The order of mention strategy did not seem to be used during sentence reading processing. However, the offline results go in the expected direction, somehow. The response times of condition SM and MS did not differ significantly ( $p < 0.06$ ), yet, response times were little longer for condition MS (223ms vs. 213ms). The accuracy rates were higher for condition SM. The offline results indicate that after processing the sentence, the information about the first event is easier to recall if the *when*-clause is the first clause. The *when*-clause indicated the first event, which was also the cause of the main clause event. As we said in the *Stimuli* section, the events had pragmatic relation and the semantic of the connective were temporal-causal. By the time the reader reached the question "What happened first?", any sort of ambiguity the connective may have caused was undone. The connective *when* may possibly have the *simultaneity* feature, such as in (11):

(11) The girl was singing *when* her mother was playing.

In (11), the relation expressed by the *when* is similar to *while* (Bever, 1970). *While* indicates an event happens at the same time another event. Additionally, at the same time the girl is singing, her mother is playing. None of those events may express one event happened before or after the order, or even that one event caused the other. On the contrary, sentences like those used in this experiment express a temporal-causal relation. We can infer a *because* and an *after* meaning in *when*. Let's compare the sentences below:

(12) When John sang, Mary played.

(13) Because John sang, Mary played.

(14) After John sang, Mary played.

The subordinate clauses in (12)-(14) designate the cause of the main clause. We have, then, a cause-effect relation between the clauses. The order cause-effect is the canonic (iconic) order, it follows the natural order. The cause is always the first event and the effect, the second. *John sang* - this event caused the effect of Mary playing. Right after John started singing, Mary started playing. Of course, at some point in time, both events happened simultaneously, however, this further information was not given in the experimental conditions. Moreover, the final question stated clearly that the needed data was the event that happened first, which means, what was the cause. Well, albeit the order effect-cause is well processed and comprehended, the cause-effect is the canonic order (De Ruiter et al, 2018). Sentences in the canonic order were easier to remember. The main-subordinate order affected the ease of late comprehension, although it eased the reading processing.

The reading times of the connective *when* in sentence-initial or sentence-final position did not show any significant difference. The type of experiment, which does not allow the reader to travel freely backwards and forwards over the phrases, might have influenced this result. However, the subordinate clause in the final position had more processing cost, compared to the subordinate clause in the first position. We believe that the information of the main clause was highly active, when the reader found the connective *when* preceding the second clause, then, the reader needed to finish the subordinate clause reading to establish the relation between the two clauses. As previously said, the reader needed more time to reorganize the events information when the *when*-clause was in final position, since this structure represent a non-iconic sentence. We claim that the subordinate clause in final position requires more processing than in initial position when it indicates events in a reverse order.

We can see that even for adults, their reading processing and interpretation are eased, when the events reflect their actual order. This way, the linguistic

information mirrors the default mental representation of the events, which costs less processing demands. Regarding the clauses ordering, the subordinate-main ordering of *when* sentences required more processing demands. However, the sentence content comprehension was improved when the *when*-sentence presented the subordinate-main structure. Diessel (2005) showed that the adverbial clause in initial position has the function of arranging the flow of the ongoing discourse because this clause works as thematic ground or orientation for the clauses that come afterward. On the same line, Junge et al. (2015) argued that there is a preference for the subordinate-main order when the *when*-clause expresses a consecutive meaning. Considering our results for the *when* sentences, in which the *when*-clause took a temporal-causal meaning, we claim that although the *when*-initial sentence costs more processing demands, this sentential structure eases the reader's comprehension of the information of the sentence. The *when*-main sentence displays the events in their actual order so, that readers do not need to reanalyze the events mapping order when they reach the end of the sentence.

## References

- Amidon, A. (1976). Children's understanding of sentences with contingent relations: Why are temporal and conditional connectives so difficult? *Journal of Experimental Child Psychology*, 22(3), 423–437. [https://doi.org/10.1016/0022-0965\(76\)90106-5](https://doi.org/10.1016/0022-0965(76)90106-5)
- Amidon, A., & Carey, P. (1972). Why five-year-olds cannot understand before and after. *Journal of Verbal Learning & Verbal Behavior*, 11(4), 417–423. [https://doi.org/10.1016/S0022-5371\(72\)80022-7](https://doi.org/10.1016/S0022-5371(72)80022-7)
- Arnold, J. E., Wasow, T., Losongco, A. & Ginstrom, R. (2000). Heaviness vs. newness: The effects of structural complexity and discourse status on constituent ordering. *Language*, 76, 28–55.
- Bever, T. G. (1970). The comprehension and memory of sentences with temporal relations. In G. B. Flores d'Arcais and W. J. M. Levelt (Eds.), *Advances in psycholinguistics*. North-Holland & American Elsevier.
- Bever, T.G. & Townsend, D.J. (1979). Perceptual mechanisms and formal properties of main and subordinate clauses. In W.E. Cooper and E.C.T. Walker (Eds.), *Sentence Processing: Psycholinguistic Studies Presented to Merrill Garrett* (pp. 159-226). Erlbaum.
- Blything, L., Davies, R. & Cain, K. (2015). Young children's comprehension of temporal relations in complex sentences: the influence of memory on performance. *Child Development*, 86(6), 1922–1934. <https://doi.org/10.1111/cdev.12412>
- Clark, E. V. (1971, June). On the acquisition of the meaning of *before* and *after*. *Journal of Verbal Learning and Verbal Behavior*, 10(3), 266–275. [https://doi.org/10.1016/S0022-5371\(71\)80054-3](https://doi.org/10.1016/S0022-5371(71)80054-3)
- Cristofaro, S. (2003). *Subordination*. Oxford University Press.
- De Ruiter, L. E., Theakston, A. L., Brandt, S. & Lieven, E. V. M. (2018). Iconicity affects children's comprehension of complex sentences: The role of semantics, clause order, input and individual differences. *Cognition*, 171, 202–224. <https://doi.org/10.1016/j.cognition.2017.10.015>
- Diessel, H. (2004). *The Acquisition of Complex Sentences*. Cambridge Studies in linguistics, 105. Cambridge University Press. <https://doi.org/10.1017/CBO9780511486531>
- Diessel, H. (2005, Jan.). Competing motivations for the ordering of main and adverbial clauses. *Linguistics*, 43(3), 449–470. DOI: 10.1515/ling.2005.43.3.449
- Diessel, H. (2008, Aug.). Iconicity of sequence: A corpus-based analysis of the positioning of temporal adverbial clauses in English. *Cognitive Linguistics*, 19(3), 465–490. DOI: 10.1515/COGL.2008.018
- Duke, W. L. (1982). *Comprehension of complex sentences conjoined with 'before' and 'after'*. Master Thesis, The University of British Columbia.
- Givón, T. (1990). *Syntax. A Functional-typological Introduction*. (v. 2). John Benjamins.
- Hall, D. P.; Caponigro, I. (2010). On the semantics of temporal *when*-clauses. In N. Li & D. Lutz (Eds.), *Proceedings of Semantics and Linguistic Theory (SALT) (20)*, pp. 544-563). Cornell University.
- Junge, B., Theakston, A. L. & Lieven, E. V. M. (2015). Given–new/new–given? Children's sensitivity to the ordering of information in complex sentences. *Applied Psycholinguistics*, 36 (2015), 589–612. doi:10.1017/S0142716413000350
- Maia, M. (2018). Computação estrutural e de conjunto na leitura de períodos: um estudo de rastreamento ocular. In: M. Maia. (Org.). *Psicolinguística e Educação* (ed. 1, v. 1, pp. 103-132). Mercado de Letras.
- Maia, M. (2019). Rastreamento ocular de períodos compostos e consciência sintática. In: Marcus

Maia (Org.), *Psicolinguística e Metacognição na Escola* (pp. 75-106). Mercado de Letras.

Moens, M. & Steedman, M. (1987). Temporal ontology in natural language. In *Proceedings of the 25<sup>th</sup> annual meeting on Association for Computational Linguistics* (ACL '87). Association for Computational Linguistics, USA, 1-7.

Musan, R. (2002). *The German Perfect – Its semantic composition and its interactions with temporal adverbials*. Humboldt-University.

Ribeiro, S. B. dos R. (2017). *O processamento da oração principal em períodos compostos por subordinação e coordenação: padrões de leitura e formação de pontos de vista*. Dissertação de mestrado. Universidade Federal do Rio de Janeiro, Faculdade de Letras, Programa de Pós-Graduação em Linguística, 81 f.

Ribeiro, S. B. dos R. & Machado, A. L. (2019). Oficina do período: identificação, desmontagem e remontagem dos pontos de vista. In Marcus Maia (Org.), *Psicolinguística e Metacognição na Escola* (133-158). Mercado de Letras.

Smith, K. & McMahon, L. (1970). Understanding order information in sentences: some recent work at Bell Laboratories. In: G.B. Flores d'Arcais & J. Levelt (Eds.), *Advances in Psycholinguistics* (pp. 253-279). Amsterdam: North Holland.

Townsend, D. J; Bever, T. G. (1978). Interclause Relations and Clausal Processing. *Journal of Verbal Learning and Verbal Behavior*, 17(5), 10.1016/S0022-5371(78)90304-3