Using eye-tracking to detect reading difficulties

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ABSTRACT

Taking into account the study of Luegi (2006), where eye movements of 20 Portuguese university students while reading text passages were analyzed, in this article we discuss some methodological issues concerning eye tracking measures to evaluate reading difficulties. Relating syntactic complexity, grammaticality and ambiguity to eye movements, we will discuss the use of many different dependent variables that indicate the immediate and delayed processes in text processing. We propose a new measure that we called *Progression-Path* which permits analyzing, in the critical region, what happens when the reader proceeds on the sentence instead of going backwards to solve a problem that s/he found (which is the most common expected behavior but not the only one, as is illustrated by some of our examples).

1. INTRODUCTION

In this paper we depart from the study of Luegi (2006) to discuss some methodological aspects related to eye tracking in studying text processing. This study incorporates assumptions and experimental materials used by Costa in 1991, but using a different experimental paradigm. The main goal of the two studies was to try to (better) understand how the human processing mechanism behaves when producing or comprehending language.

Around 1960, Noam Chomsky has argued that human beings are endowed with innate skills to acquire language, assuming the existence of a specialized organ in the human brain responsible for language acquisition (LAD – *Language Acquisition Device*). Since this assumption, linguists have been developing theories in order to identify and explain the linguistic knowledge enclosed in the LAD. On the other hand, psycholinguists have been keen to understand and explain the cognitive processes that underlie language comprehension and production. The focus of Psycholinguistics research has been to understand how linguistic information, oral or written presented, is received and processed by the brain, namely how and when each kind of linguistic information – phonological, lexical, syntactic, and semantic – enters in the processor and is integrated. The goal is to, ultimately, define a model of language comprehension and production that is able to mime the work of the brain while receiving and producing written or oral information.

Given the extent and the complexity of the processes involved and the limits of the experimental paradigms now available, investigation has been divided into different fields of research like the study of language acquisition, the study of language production or the study of language comprehension (although there is a lot of research done to combine information from all fields). In this study, our focus is to analyze language comprehension, specifically, the processing of written language, that is, reading.

Until a few decades ago, available experimental paradigms only allowed researchers to get access to the final product of comprehension, which means that researchers could only analyse the final interpretation of a sentence or a text. It was difficult then to define what and which kind of linguistic knowledge the reader (or listener) had used to end up with one interpretation over another. However, analyzing the final product of comprehension is not enough, mainly because it is known that reading, and language comprehension in general, is an incremental process (Pickering, 1999) in which readers integrate the incoming linguistic material as soon as it is perceived, so it is essential to analyze language processing as it occurs, moment-by-moment. Actually, it has been shown (for instance, by Frazier & Rayner (1982)) that readers/listeners integrate words immediately into the sentence structure that is being built without waiting for the end of the sentence. Because of that, sometimes readers realize, with the arriving of new material, that the interpretation they were comprised with is not correct (see sentence (1), for an example).

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(1) Since Jay always jogs a mile really seems like a very short distance to him.

When that happens, readers enter in what is called a garden-path situation because they interpret "a mile" as being the Direct Object (DO) of the sentence, and at the end it has to be reanalysed as the Subject of the second clause. When the readers become aware of this, they need to reanalyze their sentence's initial interpretation, or, at least, part of it. What is most interesting and what makes the reanalyze process so important to study language processing is that the disruptions on language processing are behaviourally reflected, like, for instance, in the reading speed. Behaviours during reading are tightly connect with reading fluency, and whenever there is a disruption, it is expected a change in reading behaviour (we will present some examples later). These changes, consequently, give researchers some insights about what is happening in the brain during language processing.

With the development of new experimental paradigms and with the help of more and more sophisticated equipments, it has been possible, during the last decades, to observe and analyse what is happening, more or less, precisely and immediately during reading. Available experimental paradigms allow researchers to detect when the reader felt difficulties and what s/he did to get out of them in more and more natural situations. Some examples of these types of paradigms are the reading aloud methodology, used by Costa (1991), which gives us some insights about language processing, indirectly, through production (since participants exposed to this paradigm are requested not only to read and comprehend a text or a sentence but also to produce speech). It has been shown that when facing difficulties during reading aloud there are notable variations in reading speed, in disfluencies (on type and duration) and/or in the prosodic organization of the speech, namely, in phrasing. Readers tend to produce more filled pauses, longer silent pauses, make more hesitations and/or repetitions when dealing with reading difficulties. Another widely used on-line paradigm is the one we used in the study we present in this paper, the eye tracking methodology.

Since the finding, by Émile Javal, in 1878/79, that, during reading, our eyes do not follow straightforward trough the line of text but instead we make a lot of jumps, called saccades, followed by short stops, called fixations, that has been of large interest to identify the motivations of these behaviours (for a large review of many aspects of eye tracking, see Rayner (1998) or Rayner (2009)). Although it is obviously that there is a great motor motivation, since our vision acuity is limited and so we need to move our eye to collect new information (not only during reading but in everyday life tasks), it has been proved that linguistic aspects like lexical frequency, syntactic complexity or semantic context may influence and change reading behaviour (see, for instance, Just & Carpenter (1980), or more recently, Clifton, Staub & Rayner (2007)). The assumptions that there is a direct relation between eye behaviour and the processing of linguistic properties and, moreover, that eye movements reflect cognitive processes (Liversedge & Findlay, 2000) turned eye tracking into a powerful instrument to investigate language processing during reading and, also, more recently, during oral language comprehension (with the Visual World Paradigm). It is assumed that our eyes reflect (more or less directly) not only the difficulties that the brain may be dealing with during reading but also how someone is interpreting a sentence. Moreover, eye tracking allows us to analyse language comprehension in real time. This is why the use of this methodology has been widely spread during the last decades and has benefited from newer and more powerful equipments which, in turn, make research more refined and reliable.

Using eye tracking, in the study shortly presented in this paper, we had two main goals: the first was to identify if the theme of a text and also the syntactic complexity of some sentences would affect language processing and how these difficulties would be reflected on eye movement; secondly, we wanted to verify if results would be the same, or at least approximated, using different methodologies (reading aloud and eye tracking). In accordance with the ETVCE2010 main purpose: *focus on the use of eye tracking as a valuable method in different research fields*, in this paper we will focus mainly on some relevant aspects related with the eye tracking methodology that the study we developed lead us to.

2. EXPERIMENT

2.1 Method

2.1.1 Participants.

Twenty university students participated in this study, which was done at the University of Lisbon, Portugal. All participants were native speakers of European Portuguese, with an age average of 22 years and 9 months, and had normal or corrected-to-normal vision.

All participants were informed about the purpose and the procedure of the study and gave us their written consent to divulge the results as long as it was done anonymously.

2.1.2 Materials

As stimuli we used two texts that had been previously used by Costa (1991). The two texts have a very similar textual structure in that both have a title which introduces the theme, they have identical structural information in terms of the distribution of the theme or paragraph organisation, and both texts have a concluding paragraph that is introduced by a rhetorical question. Both texts have approximately the same number of words. Likewise, at the level of syntactic structure, both texts are fairly similar, being the sentences' syntactic structure of the same type along the two texts.

Despite their similarities, referred above, the two texts differ in what concerns the familiarity of their theme, taking into consideration the background knowledge of our sample: one text is about a well-known topic, *Campo de Ourique* (T1), while the other is about a scientific topic, *O Isolamento termo-acústico* (T2), far-away from the readers' universe of reference and, consequently, with less frequent words. Taking into account the background knowledge of the subjects, the difference between text themes will have an impact on reading, producing the independent variable *Theme*.

Also, two versions of each text were made: a control version (T) and a version in which some syntactical structures were manipulated (T'). This manipulation gave rise to the independent variable: *Syntactic Level Degradation*. The target syntactic structures were chosen on the basis of their grammatical properties in European Portuguese (henceforth EP). Contexts 1, 2 and 4 are completely ungrammatical in EP while context 3 is only temporary ambiguous. Since syntactic manipulations were similar on both texts, we will present bellow only examples from T2 (the contexts under study are in italic). The examples T2' illustrate the syntactic degraded structures.

- Context 1 (C1): the clitic (that is, *se*) was placed in post-verbal position in a relative clause, where proclisis is required, setting up an ungrammatical situation in EP.

  T2 – os múltiplos sons de choque, | *que se captam* $|_A$ *no interior de cada edifício* $|_B$

  the multiple sounds of crashes, | *which* (clitic) *are captured* | *inside each building*$|_B$

  T2'– os múltiplos sons de choque, | *que captam-se* $|_A$ *no interior de cada edifício* $|_B$

  the multiple sounds of crashes, | *which are captured-*(clitic) | *inside each building*$|_B$

- Context 2 (C2): the clitic (*-se*) which acts as an internal argument of the verb is omitted, giving rise to an ungrammatical sentence.

  T2 – A resolução deste problema […] | *centra-se* $|_A$ *na existência de meios técnicos actuantes na oposição à propagação de ruídos.* $|_B$

  The solution of this problem […] | *centers itself*$_{(clitic)}$ $|_A$ *on the existence of technical means countering the propagation of noise.* $|_B$

  T2'– A resolução deste problema […] | *centra* $|_A$ *na existência de meios técnicos actuantes na oposição à propagação de ruídos.* $|_B$

  The solution of this problem […] | *centers* $|_A$ *on the existence of technical means countering the propagation of noise.* $|_B$

- Context 3 (C3): the Subject is in a post-verbal position in a non-marked declarative clause, giving rise to temporary ambiguity because the NP to the right of the transitive Verb may be interpreted as a Subject or as an Object in a null Subject construction.

  T2 – | *o painel ISOLPAN apresenta vantagens excepcionais* $|_A$

  | *the ISOPLAN panels display exceptional advantages* $|_A$

  T2' – | *apresentam os painéis ISOLPAN vantagens excepcionais* $|_A$

  | *display the ISOPLAN panels exceptional advantages* $|_A$

- Context 4 (C4): the Subject precedes the Verb in a WH-question, where post verbal Subject is obligatory, thus resulting in an ungrammatical structure.

T2 – | *Como actuam os especialistas em isolamento*? |$_A$ *Defendem que a eleição de materiais e de técnicas* |$_B$

How do actuate the insulation specialists? |$_A$ *They argue that choosing the materials and the techniques* |$_B$

T2' – | *Como os especialistas em isolamento actuam? Refendem que a eleição de materiais e de técnicas* |$_B$

| *How do the insulation specialists actuate?* |$_A$ *They argue that choosing the materials and the techniques* |$_B$

Within each of the contexts, different local regions of analysis were defined and are signalled out by vertical bars (|) in the examples presented above. As it may be seen, in almost all contexts there were two regions of interest, with an exception for Context 3, were only one region was defined. The division of contexts into regions of analysis was set up because it is predicted that, firstly, the ungrammatical or ambiguous structures are not always immediately identified in the region in which they occur, but may only be experienced in the following words. Secondly, even if they are detected immediately, some effects of the detection may occur afterwards. In other words, it may occur a phenomenon known as the spill-over effect: reading time on a word may be increased by difficulties in the processing of the previous word, indicating that the processing of that word was not finished when it was abandoned and a new word was fixated.

The first region, Region A, is always the critical one and covers the places where the problem has been set. The second region of analysis, Region B, is called the post-critical region and includes the words coming after the problem; this is the region where it is expected that, as new material is perceived, the problem will be confirmed and solved, or, probably, from where regressions will be made to the region where the problem originated.

2.1.3 Apparatus

Eye movements were registered with an ASL 504 system. This eye tracker detects both corneal and the pupil reflexion and the registration is made at a rate of 60Hz. The spatial accuracy of the system is of 0,5º and a chinrest was used to maintain accuracy, since it limits head movements.

2.1.4 Procedure.

The texts were divided into three parts and were presented on different PowerPoint slides on a computer screen.

The 20 participants were divided into two subgroups: 10 participants read T1 and T2'; the other 10 participants read T1' and T2. To avoid effects of order, reading was done alternately: half of the participants of each group read first T1 while the remaining participants read first T2.

At the beginning of the experiment, participants were informed about the procedure. They were told that they were going to read two texts on a computer screen, while their eye movements were registered, and that they should pay attention and comprehend the text, since that at the end of each text they would have to answer to some questions about what they had just read. After the instructions had been read and explained in detail to the participants, the equipment was calibrated and then, in order to check whether it was working properly, participants read a small sample text. If needed, the equipment was newly adjusted or if it was satisfactory, the task was begun.

2.1.5 Dependent variables.

Since this was our first study using eye tracking to analyse text reading, and since, usually, most studies are focused on sentence reading, we decided to analyse many different dependent variables (for a review, see Hyönä, Lorch & Rinck (2003)). For global text reading we analysed: (i) Total Reading Time (TRT) – sum of all fixations made while reading the entire text; (ii) Total Number of Fixations (TNF) – number of fixations made while reading the all text; (iii) Mean Fixation Duration (MFD) – TRT divided by the TNF. However, for each region of each context we analysed: TRT, TNF and MFD during first-pass reading (first-pass reading measures include any eye movements made since the eyes first entered a region until it is left it to the right or to the left), second-pass reading (include all eye movements made in a region for the second time that the eyes entered that region until it is left for good), and total reading (sum of the values of the first-pass and of the second-pass). We also analysed the Number of Internal Regressions (NIR), the Regression-Path (sum of the time spent on a region since it was entered for the first time until the eyes progressed for the right hand side of that region including time spent anywhere on the left of that

region) and the Progression-Path. This last measure was firstly introduced by us in Luegi (2006). In this measure we consider all eye movements made since a region is first entered until it is completely abandoned, summing not only eye movements made on the region but also on any other part of the sentence, to the right or to the left of the region under analysis. Usually only the Regression-Path is measured, since what is expected is that when entering a region a reader may experience some difficulties and need to go back to look for information that may be helpful to solve the problem s/he encountered. However, we realised that this is not always the case. Sometimes the information that may help the reader to get out of the difficulties s/he is experiencing is only to the right of the region where the problem is, and the reader must go on trough the sentence to find the solution for the problem (see Luegi (2006) for further details and examples of this dependent variable).

We analyzed not only reading behaviours during the reading of a region but also during the reading of the entire context, summing values registered in Region A with the values registered in Region B.

For global reading (reading of the all text), we analysed all meaningful contrasts, that means, T1 against T1', T2 against T2', T1 against T2, and T1' against T2'. For context analyses we contrasted only reading behaviour between texts with the same theme, that is, T1 versus T1', and T2 versus T2'.

2.1.6 Hypothesis.

First: a text of a specific knowledge domain, and, consequently, with technical vocabulary, leads to a processing overload that will be reflected in an increase in, at least, one of the measured dependent variables; Second: syntactically manipulated structures, ungrammatical or only ambiguous, may disrupt reading processing and this disruption is expected to be reflected on eye movements behaviour, leading to an increase in, at least, one of the measured dependent variables.

3. RESULTS

In Table 1 we present the global reading results of the four texts.

Table 1. – *Variables measured during the global text reading: meaning values for TRT (Total Reading Time), TNF (Total Number of Fixations), and MFD (Mean Fixation Duration) during the reading of T1, T1', T2, and T2'. (The [s] indicates that values are presented in seconds.)*

		T1	T1'	T2	T2'
TRT [s]	M	47,871	46,654	51,222	54,882
	SD	6,727	10,293	10,308	9,168
TNF	M	167,5	164,3	169,3	186,5
	SD	12,817	19,534	16,33	16,761
MFD [s]	M	0,286	0,282	0,302	0,293
	SD	0,033	0,036	0,048	0,029

Differences were only statistically significant (at a level of significance of 5%: p-value<0,05): for TRT, between T1' (M=46,654 seconds) and T2' (M=54,882 seconds), [t(18) = 1,888; p<0,05], and for TNF between T2 (M=169,3 fixations) and T2' (M=186,5 fixations), [t(18) = 2,324; p<0,05], and between T1' (M=164,3 fixations) and T2' (186,5 fixations), [t(18)= -2,727; p<0,05].

For the sake of conciseness and due to space limitations, we will present, for the analyses of the contexts, only the differences that were statistical significant (for a global analysis of results, please see Luegi (2006)). (Values in gray on the tables are not statistical different) .When comparing T1 with T1' we only found statistical significant differences in Context 1 (see Table 2).

In this context, differences were found in the first region (Region A) during the second-pass reading, with higher values in TRT for T1' (M=0,322 seconds) when comparing with T1 (M=0,032 seconds), [u=28,500; p<0,05], and in the TNF, with higher values for T1' (M=1,1 fixations) than in (M=0,1 fixations), [u=28,000; p<0,05]; in TRT and TNF in the reading of the all region (sum of the values of first and second-pass reading), with higher values for T1' in both measures: TRT, T1 (M=0,544 seconds) vs. T1' (M=0,991 seconds), [t(18)= -2,205; p<0,05]; TNF, T1 (M=1,8 fixations) vs. T1' (M=3,0 fixations); and in the NIR, also with higher values for T1' (M=0,4 regressions) than for T1 (M=0,0 regressions),

[u=30,000; p<0,05]. In Region B, there were only differences in the number of fixations during the first-pass reading, this time, with higher values for T1 (M=5,0 fixations) than for T1'(M=3,2 fixations), [u= 13,500; p<0,05]. This difference may be explained by the fact that when entering Region B of T1', readers realize that there is a problem with that sentence and almost immediately go back to the region where the problem is. On the contrary, in T1, readers continue in the Region until abandoning it completely. This explanation is, in our opinion, confirmed by the fact that the TNF in the all region are equal, although differently distributed. Also, the number of fixations made in Region A during the second regions support this explanation, since there is a difference between the number of fixations during the second-pass reading of T1 and of T1' (this last with a higher number of fixations than the former). So, readers did not detect the problem until they entered the second region of text, which means that the ungrammaticality was not detected immediately.

Table 2. – *Variables measured during the reading of Context 1 of T1. (The [s] indicates that values are presented in seconds.)*

		Context 1			
		Region A		Region B	
		T1	T1'	T1	T1'
FR.TNF	M	1,7	1,9	5,0	3,2
	SD	0,7	1,1	1,3	1,1
SR.TRT [s]	M	0,032	0,322	0,100	0,517
	SD	0,100	0,388	0,317	1,023
SR.TNF	M	0,1	1,1	0,3	1,9
	SD	0,3	1,3	0,9	3,4
TRT [s]	M	0,544	0,991	1,589	1,490
	SD	0,326	0,552	0,573	0,823
TNF	M	1,8	3,0	5,3	5,1
	SD	0,6	1,2	1,4	2,6
NIR	M	0,0	0,4	0,7	0,8
	SD	0,0	0,5	0,5	1,1
Progr.Path [s]	M	0,230	0,790	0,000	0,482
	SD	0,728	1,077	0,000	1,525

We would finally like to point out the difference between T1 and T1', in Context 1, in the values of the Progression-Path measure. Although it is not statistically significant, it is clear that there is a difference between T1 and T1', with 0,230 seconds and 0,790 seconds, respectively. We will regress to this matter on the General Discussion.

When comparing the two versions of T2, differences were found in all contexts.

In Context 1, as may be seen in Table 3, there were differences, in Region A, in TRT between T2 (M=0,424 seconds) and T2' (M=0,716 seconds) [t(9,993)= -2,613; p<0,05] and in the TNF [u= 19,500; p<0,05], with higher values in T2' (M=2,5 fixations) than in T2 (M=1,5 fixations).

Table 3. – *Variables measured during the reading of Context 1 of T2. (The [s] indicates that values are presented in seconds.)*

		Context 1					
		Region A		Region B		Region A+B	
		T2	T2'	T2	T2'	T2	T2'
TRT [s]	M	0,424	0,716	0,973	1,471	1,397	2,187
	SD	0,081	0,344	0,272	0,434	0,320	0,633
TRT.TNF	M	1,5	2,5	3,5	5,1	5,0	7,6
	SD	0,5	0,9	1,0	1,6	1,2	2,0
NIR	M	0,0	0,2	0,2	0,8	0,2	1,0

	SD	0,0	0,4	0,4	0,9	0,4	1,1

In Region B, differences were found in TRT, [t(18)= -3,079; p<0,05], with higher values in T2' (M=1,471 seconds) than in T2 (M=0,973 seconds), and also, with the same pattern, in the TNF [u= 19,500; p<0,05], T2 (M=3,4 fixations) and T2' (M=5,1 fixations). In terms of the all context, the differences are significant in the TRT [t(13,316)= -3,523; p<0,05], again with higher values in T2' (M=2,187 seconds) than in T2 (M=1,397 seconds); in the TNF, [u= 11,000; p<0,05], with more fixations in T2' (M=7,6 fixations) than in T2 (M=5,0 fixations); and in the NIR, [u= 27,000; p<0,05], higher in T2' (M=1,0 fixations) than in T2 (M=0,2 fixations).

In Context 2 (Table 4), differences were found in Region A and also in Region B (see Table 4). In Region A, there are differences, during the first-pass reading, in the TRT, [t(18)= 2,317; p<0,05], this time, with higher values in T2 (M=3,085 seconds) than in T2' (M=1,832 seconds), and also in the TNF, [t(13,925)= 2,533; p<0,05], also with higher values in T2 (M=9,5 fixations) than in T2' (M=5,7 fixations). In Region B, during the second reading (that is, during the re-reading of the region), differences are statistical significant in TRT, [u= 27,000; p<0,05], with more time spent during the reading of T2' (M=1,559 seconds) than during the reading of T2 (M=0,159 seconds), and in TNF, [u= 27,500; p<0,05], also higher in T2' (M=6,1 fixations) than in T2 (M=0,4 fixations).

Table 4. – *Variables measured during the reading of Context 2 of T2. (The [s] indicates that values are presented in seconds.)*

		Context 2			
		Region A		Region B	
		T2	T2'	T2	T2'
FR.TRT [s]	M	0,279	0,237	3,085	1,832
	SD	0,138	0,123	0,911	1,447
FR.TNF	M	1,1	0,9	9,5	5,7
	SD	0,3	0,3	2,3	4,2
SR.TRT [s]	M	0,032	0,147	0,159	1,559
	SD	0,100	0,201	0,501	1,683
SR.TNF	M	0,1	0,5	0,4	6,1
	SD	0,3	0,7	1,3	6,6
Regr.Path [s]	M	0,060	0,062	0,330	2,028
	SD	0,190	0,195	1,045	2,178
Progr.Path [s]	M	0,000	0,487	0,000	0,000
	SD	0,000	0,659	0,000	0,000

In this context, as may be observed by the analysis of the values of first- and second-pass of Region A and Region B, respectively, it is clear that the readers detected the problem as soon as they entered the post-critical region and went back to the critical one to verify or solve the problem, leading to a decrease on the firs-pass reading of Region B and an increase of second-pass reading of Region A. This behavior may also be observed in the time of the Progression-Path of Region A, and on the time of the Regression-Path of Region B. In Region A, the Progression-Path [u= 30,000; p<0,05] value was higher in T2'(M=0,487 seconds) than in T2 (M=0 seconds) and in Region B, the same happened but with the Regression-Path, [u= 28,500; p<0,05], T2' with (M=2,028 seconds) and T2 with (M=0,330 seconds).

In Context 3, the TNF was higher in T2' (M=8,1 fixations) than in T2 (M=6,1 fixations), [t(18)= -2,496; p<0,05], as may be seen in Table 5.

Table 5. – *Variables measured during the reading of Context 3 of T2.*

		Context 3	
		T2	**T2'**
TNF	M	6,1	8,1

	SD	1,4	2,1

In what concerns Context 4 (see Table 6), there were statistically significant differences in the TRT, [u= 15,000; p<0,05], in Region A, with lower reading time for T2 (M=1,477 seconds) than for T2' (M=2,126 seconds), and in the context (Region A + B), [u= 18,000; p<0,05], (M=4,284 seconds) for in T2' and (M=3,375 seconds) in T2. TNF was also higher in T2' than in T2 in Region B, [t(18)= -2,900; p<0,05], the first with (M=7,6 fixations) and the second with (M=5,6 fixations), and in the all context, [t(18)= -3,356; p<0,05], T2' (M=14,9 fixations) and T2 (M=10,7 fixations).

Table 6. – *Variables measured during the reading of Context 4 of T2. (The [s] indicates that values are presented in seconds.)*

		Context 4					
		Region A		Region B		Region A+B	
		T2	T2'	T2	T2'	T2	T2'
TRT [s]	M	1,477	2,126	1,899	2,157	3,375	4,284
	SD	0,752	0,401	0,996	0,553	1,652	0,776
TRT.TNF	M	5,1	7,3	5,6	7,6	10,7	14,9
	SD	1,8	2,9	1,3	1,8	2,0	3,4

3. CONCLUSIONS

As we mentioned in the introduction, in this paper we would like to focus on some aspects about the eye tracking methodology that are illustrated by the results presented in the previous section and that were not explored before. However, briefly, as is reflected on the results we have presented, we may conclude that our hypotheses were confirmed: there was an increase in reading time during the text with a more specific theme and also in the most complex syntactic structures. This last result was more accentuate when theme and syntactic complexity were combined, that is, syntactic complexity had a greater impact during the reading of the less frequent theme (for further details, see Luegi (2006) and Luegi, Costa & Faria (2007)).

In what concerns the methodology, generally, the results of this study, as results of many other studies, allow us to confirm that eye tracking is a very fine grained technique, allowing researchers not only to identify reading difficulties, but also, and more importantly, to detect when and where these difficulties are precisely perceived and solved by the reader. Frenck-Mestre (2005), for instance, defends that eye tracking methodology is the best experimental paradigm to study bilingualism, since it allows the analysis of different phases of the language processing (automatic versus conscious or controlled mechanisms).

Moreover, and as a direct consequence of the adopted experimental design, our results show that manipulations on different kinds of syntactic structures can motivate different types of reading behaviors. In this study we analyzed many different linguistic issues, altogether, like word order on declarative and on relative sentences, and on WH- questions, or deletion of a verb internal obligatory complement. Our results showed that the detection and resolution of each problem was different among conditions, as difficulties felt by readers were reflected on different variables, for instance: in one condition there were differences in the first-pass reading time, while in another condition, for instance, difficulties were revealed in the number of fixations in the total reading time, and so on.

Actually, eye tracking methodology is the only one that allows the analysis of so many dependent variables to investigate language processing. This possibility gives researcher the chance to analyze reading processing as the sentence unfolds, from the first moment that a word, a phrase or a clause is fixated until it is abandoned.

In sum, eye tracking methodology allows researchers not only to know more about the reading processing itself but also, as it is illustrated by our results, to identify different types of reading behaviors as different syntactic structures are being processed. Also, the possibility of analyzing measures such as first-pass and second-pass reading give researchers the chance to clear identify when and where reading is disrupted, transforming an automatic processing in a controlled one, and when reanalysis is initiated.

Finally we would like to argue for the importance of the Progression-Path measure. As has been shown in the presented study, for instance in Context 1 of T1 and Context 2 of T2, this measure is helpful to analyze what really happens on the critical region (the focus of interest). What is expected in almost all

eye tracking studies, due to the kind of the structures that are analyzed, is that when facing a problem the reader goes back (making what is called regressive saccades) to find a solution. However, as it is illustrated in some of our examples, sometimes it is not possible to find the solution in the previous words or phrases and so it is mandatory to search on the following ones. We do believe that the reader, immediately after detecting a problem, is certain about where to find the information s/he needs to solve the problem (at least, surely, if it is or it is not to the left/back). So, having this in mind, we argue that what should be measured in the critical region is both Regression and Progression-Path, since these measures give different information. While the former, when measured on the critical region, only gives us any information if the reader goes back, the last allows us to detect if the reader progressed into the sentence to search for useful information.

Acknowledgements: We would like to thank to the Calouste Gulbenkian Foundation for the support on the acquisition of the eye tracking equipment.

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